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ABSTRACT

The argument over economic development and environmental sustainability took center stage in the late 1960s and early 1970s as many believed the capacity of the earth to support the population was being reached. In the early 1980s the arguments receded but have reemerged as atmospheric problems and petroleum supplies are again hot topics. The purpose of this forum was to discuss whether environmental crises will cause a reversal in world development and how should development of the world proceed. Eight papers are included: (1) "Development Pressures on the World's Peasants: Environmental Trends and Development Lessons from the Bottom Up" (Timothy C. Weiskel); (2) "Environmental Opportunities and Limits for Development" (Reid A. Bryson); (3) "Global Sustainability and Food Production" (Robert L. Clodius); (4) "The Red Queen Syndrome: Running Faster--Going Nowhere?" (John E. Ross); (5) "Environmental Criteria and World Bank Loans" (Robert J. A. Goodland); (6) "Decline of the World's Tropical Forests" (James D. Nations); (7) "In Defense of Development" (Julian L. Simon); and (8) "Global Balances in the 21st Century" (Russell W. Peterson). (MVL)

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Environment and Development: Building Sustainable Societies

Lectures from the 1987 Summer Forum
at the University of Wisconsin-Madison

John E. Ross, Coordinator

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University of Wisconsin-Madison

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Preface

In the summer of 1987 the University of Wisconsin-Madison's Institute for Environmental Studies and Division of Summer Sessions cosponsored a forum titled, *Environment and Development: Building Sustainable Societies.*

The forum featured eight speakers with varying views on one of the significant issues of our time. The speakers, in order of their lectures, were Timothy C. Weiskel, Reid A. Bryson, Robert L. Clodius, John E. Ross, Robert J. A. Goodland, James D. Nations, Julian Simon, and Russell W. Peterson. Their biographical sketches appear on the pages following this preface.

The argument over economic development and environmental sustainability took center stage in the late 1960s and early 1970s, propelled by a series of global modeling studies that forecast economic decline and even collapse because, it was believed by many, we are overreaching the capacity of the earth to support us.

In the early 1980s the arguments receded, certainly in part because of the decline in petroleum prices. Then, when global atmospheric problems emerged and the perception that petroleum supplies are finite became more obvious, the global sustainability debaters moved back to center stage.

There is no consensus among the debaters about whether environmental crises will cause a reversal in world development. On the other hand, encouraging new technologies sit on the horizon. But there are also storm clouds and the dull sound of thunder out there. The argument is not really whether economic development should be deliberately halted, because problems of the disadvantaged are still acute. Rather, it is about how development should procede -- and at what rate -- to maintain sustainable societies across the generations. There is a general recognition that current policies and instruments do not do all we want them to do in maintaining a viable environment.

It is in the spirit of open debate on an extremely complex issue that the forum was convened. This volume includes edited versions of the eight lectures, preceded by an introduction designed to set the parameters of the debate as it evolved in the forum.

The Speakers

Timothy C. Weiskel, an economic anthropologist, is a Henry Luce fellow at Harvard University. He has studied the historical evolution of agroecosystems in the Third World, particularly West Africa, where he analyzed peasant reactions to colonial and postcolonial development schemes in French-speaking countries.

Weiskel's work has combined economic and ecological anthropology with emphasis on documenting historical transformations in relations between rural people and the land. His concern about global trends of resources depletion in agroecosystems has prompted him to focus on the political economy of tropical deforestation, soil erosion, and plant genetic collapse.

Weiskel has a B.A. in anthropology and history from Yale and completed graduate degrees in both fields at Oxford University as a Danforth fellow and Rhodes scholar. He has taught anthropology at Williams College, Yale, and Harvard.

Reid A. Bryson, emeritus professor of environmental studies, meteorology, and geography at UW-Madison, is an internationally known climatologist who has devoted much of his scientific career to understanding the history of climate change and perfecting long-range climate forecasting.

In his nearly 40 years as a member of the UW-Madison faculty, Bryson founded the Department of Meteorology and served as the first director of the Institute for Environmental Studies. Now retired from the faculty, he continues to conduct research in paleoclimatology and to write. He has written 200 professional articles and written or coauthored five books.

A fellow of the National Association for the Advancement of Science, he has served on committees for the National Academy of Science/National Research Council, the National Science Foundation, and other scientific organizations. Agencies ranging from the United Nations Food and Agriculture Organization to Environment Canada have sought his expertise as a consultant.

Born in Detroit, Bryson earned his B.A. in geology at Denison University and a Ph.D. in meteorology from the University of Chicago.

Robert L. Clodius is widely recognized for his work in agricultural policy and economics. Former editor of the the *Journal of Farm Economics*, he has been a consultant to the U.S. departments of State and Agriculture, the Ford and Rockefeller foundations, the University of East Africa, and the government of Sierra Leone. He also has served as chairman of the advisory committee for the National Center on Agricultural Policy at Resources for the Future.

Since 1978, he has been president of the National Association of State Universties and Land-Grant Colleges, which represents 145 of the nation's major public universities. Earlier, he served 28 years as a faculty member and administrator at UW-Madison, where he was a professor of agricultural economics, economics, and educational administration. He directed an overseas university development project in Indonesia from 1971 to 1977. As an administrator, he was associate dean of the Graduate School, chairman of the Department of Agricultural Economics, and acting provost. He also served as academic vice president, executive vice president, and academic president of the university's central administration.

A native of Walla Walla, Washington, Clodius has bachelor's and doctoral degrees from the University of California-Berkeley.

John E. Ross (Summer Forum Coordinator) is a professor of agricultural journalism and environmental studies at UW-Madison. As associate director of the Institute for Environmental Studies from 1970 to 1978, he helped develop the institute's research and instructional programs. He currently teaches IES courses on environmental decisionmaking and on social perspectives in environmental studies.

From 1977 to 1979, Ross headed and in-depth study of international resource policies sponsored jointly by UW-Madison, the Organization of Petroleum Exporting Countries, the Kuwait Fund for Economic Development, and the Arab Fund for Social and Economic Development.

Ross has a bachelor's degree in animal husbandry from Oregon State University, a master's degree in agricultural journalism from UW-Madison, and a doctorate in mass communications, also from UW-Madison. He joined the university's faculty in 1956.

Robert J. A. Goodland is an ecologist with the Office of Environmental Affairs at the World Bank in Washington, D.C. He has been a professor of environmental sciences at McGill University in Montreal and professor of ecology at the University of Brasilia in Brazil. He also has taught at the Organization for Tropical Studies in Costa Rica and the National Institute for Amazonian Research in Manaus, Brazil.

Goodland has published nine books and approximately 59 other publications. His recent works include *Environmental Management in Tropical Agriculture, Ecology of Cerrado,* and *Environmental Assessment of the Tucurui Hydroproject, Brazil.* He also has served as assistant director and chairman of environment assessment at Cary Arboretum in Millbrook, New York.

Goodland has a bachelor's degree in biology and master's and doctoral degrees in ecology, all from McGill.

James D. Nations is director of research for the Center for Human Ecology in Austin, Texas, a conservation research organization dedicated to the wise use of natural resources in the Latin American tropics.

Nations received a Ph.D. in ecological anthropology from Southern Methodist University in 1979 after studying the Lacadan Maya of Chiapas, Mexico, for three years. He subsequently completed a two-year postdoctoral study, funded by the Tinker Foundation, on the human use of tropical resources in Mexico and Central America through the Center for Latin American Studies at the University of California-Berkeley.

Since that time he has been a consultant to the U.S. Agency for International Development, World Wildlife Fund, National Wildlife Federation, Conservation Foundation, World Resources Institute, Rainforest Action Network, National Academy of Sciences, Smithsonian Institution, and the national parks and forestry departments of Equador, Guatemala, and Honduras.

Nations has lectured on tropical forests throughout the United States and published numerous scholarly and popular articles on the subject. He also has produced environmental education materials for a number of private conservation groups.

Julian L. Simon is a professor of business and social science at the University of Maryland. He has been an adjunct scholar at the Heritage Foundation, a public policy organization based in Washington, D.C. Before joining the University of Maryland in 1983, he was a professor of economics and business administration at the University of Illinois for 14 years.

Simon is an outspoken advocate of population growth and critic of warnings that the world's natural resources are being depleted and its environmental quality is deteriorating. His books on the subject include *The Economics of Population Growth* and *The Ultimate Resource*, published by Princeton University Press in 1977 and 1984, respectively. He also edited, with Herman Kahn, *The Resourceful Earth: A Response to the Global 2000 Report*, published in 1984 by Basil Blackwell. In all, he has written or coauthored nearly 20 books and more than 200 articles for publications ranging from academic journals to the .

Simon has a B.A. in experimental psychology from Harvard University and an M.B.A. and Ph.D. in business economics from the University of Chicago.

Russell W. Peterson is one of the nation's leading environmental advocates, having served as chairman of the President's Council on Environmental Quality from 1973 to 1976 and as president and chief executive officer of the National Audubon Society from 1979 to 1985.

He is president of the Better World Society, vice president and regional councilor of the International Union for the Conservation of Nature and Natural Resources, president of the International Council for Bird Preservation, and a director of the Alliance to Save Energy and the Population Crisis Committee. He also has chaired the Global Tomorrow Coalition.

Peterson was governor of Delaware from 1979 to 1973 and headed the congressional Office of Technology Assessment from January 1978 to March 1979. Before entering public life, he was employed for 26 years with the Dupont Company, where he held a number of positions culminating with the directorship of the company's Research and Development Division.

A native of Portage, Wisconsin, he earned a Ph.D. in chemistry at UW-Madison in 1942. During the summer of 1987, he returned to the university as a visiting professor in the Institute for Environmental Studies to teach a course titled, "Prospects for the Global Environment."

Introduction

John E. Ross

Among the countless centuries of earth's time, the 20th stands unique.

It is the century when humans found, through scientific progress, answers that became the opportunities perceived by technologists and that led to profound social changes -- most significantly, to an explosion in human population and increases in per capita consumption of resources. These conditions had not previously existed in the human experience. The 20th century is where they came together -- the discoveries, the applications, and the consequences. Earlier civilizations only vaguely imagined our condition before they faltered and faded, although they certainly exploited the technologies and the resources they understood.

So *natural growth* in our century has turned into an unprecedented epoch of *economic expansion*. The term "expansion" rather than the term "growth" can be justified because the changes are so fundamentally different from previous experience.

Biology on earth was, and is, well adjusted to natural growth. One of the obvious characteristics of biology is population growth often followed by decline -- sometimes slowly, sometimes precipitously. Thus *fluctuation* in populations is a response to changes in the environment -- diurnal, lunar, seasonal, and cyclical. The environmental rhythms are the inevitable governors of growth. Competition for specific, limited resources is the mechanism by which the governor operates and species populations fluctuate. There is always risk -- for individuals, for populations, and for ecosystems.

And, over time, the menagerie of life changes.

Economic expansion replaces natural governance with technological governance. The new governance seeks to limit variations in the environment and in risk and to limit fluctuations in population while -- and this is the key -- allowing for continued growth.

As the 20th century nears its end, as new problems loom on the horizon, there is the inevitable and necessary debate over the consequences of economic expansion.

One world view warns that global environmental breakdown is inevitable if the world continues its present course of exponential increases in population, rates of resource use, and pollution loadings. This point of view argues that precipitous decline is a more likely description than gentle fluctuation because of the recent rates of change. This view also sees causes of the decline as a looming crisis in energy supplies and the impact of its use, a steady erosion in our ability to expand food supplies, a decreasing ability to maintain public health, and, most important, a negative impact on global natural networks, particularly those related to the atmosphere. The environmental breakdown view holds that we are moving inexorably toward an era of *general* scarcity, which could mean a rapid decline from present population levels and rates of resource consumption or at least an orderly retreat from a condition of rapid economic expansion. In either case a recovery would be drawn out, at a minimum, over decades, maybe even centuries. The arithmetic of exponential growth is a powerful ally in this argument.

Another world view holds that new technological alternatives generated through basic and applied research will ease the current problems of resource exploitation and subdue the health risks. In fact, this view argues that human history is one of continual reconstruction of the

world and of the basics in nature. We can, according to this view, maintain a steadily improving lifestyle and avoid the risks imbedded in natural fluctuations and change. The view voices confidence in the concept of expansion, arguing that we can move ahead at a pace limited by technology and our cleverness in applying it. The argument is that new technology can overcome current resource limitations. Population increase is thus not a liability. Rather, it generates economic value in the form of productive labor. In fact, we can make the environment "stable" for human occupation of the earth indefinitely. This world view has a powerful ally in our recent history.

The first of these world views, the one warning of breakdown, can be called environmental determinism. The boundary conditions imposed by nature remain real and close by. Land's leash is short. We travel on nature's cycles. Societies could retreat to cottage technology, to the neolithic condition, or to the paleolithic. Or we could induce our own extinction in short order rather than through a genetic drift into unfitness or a radical change of and by nature. After all, as *homo erectus* and then as *homo sapiens*, we've been around a couple of million years, which is about average for vertebrate species. But in our case, there's no evidence and little likelihood that a different species would emerge in "our line."

The second view can be called technological determinism. Environmental limits can be overcome. It is a matter of ingenuity, which we have in great abundance; a matter of will; and a matter of money. Bioengineering, for example, opens new horizons.

While these two views may appear starkly opposite as stated here, they should be so stated to assure that the extremes of the alternative outcomes are on the table for discussion.

It is worth noting that the term "resources" is inherently human-centered. The formal definition of resources is "something that lies ready for use or that can be drawn upon for aid or to take care of a need." The "need" in this definition is assumed to be human -- thus a dogma of anthropomorphism. The need of a resource may be for survival, or for subsistence by individuals, or for economic exploitation in the sense of power over others.

If we place the word "natural" before the word "resource," it is assumed we mean usable things that flow from natural processes generated in the past or under way now. We can, in this definition, restrict the definition of natural resources to such things as fossil hydrocarbons and iron ore deposits, where humans had no role in their generation, or we could accept some human manipulation, as in agriculture, and still "economize" largely within the bounds of natural resources.

At this time, however, we are in the process of adding the adjective "synthetic" in front of the word "resources." And we are entering a new era that can be called synthelithic: the age of synthetic stone -- the new-stone age.

Nature has inherently recognized synthesis, but economic expansion has tested nature's supply. We have not yet crossed the line into a synthelithic existence, so we are somewhere in between neolithic and synthelithic. If this is true, then industrialism is an interval, a short one at that, in the two million years of existence of "modern" humans. There is no assurance that if we achieved a synthelithic existence it would be as persistent over the centuries as the paleo- or neolithic conditions were, although that must be our assumption because we seem so impatient with the quality and quantity of natural resources and rush forward on the river of destiny. While we will continue to operate within the basic "laws" of physics, chemistry, mathematics, and biology to "improve" on nature, we clearly are now committed to technical synthesis. This is the new condition of the 20th century.

Fundamental to our current condition and our judgment of the availability of resources is the idea that *need* for resources is socially defined as well as survival-defined. Thus, social expectation becomes intermixed with physical and biological need. In fact, much of what is synthetically generated is not a physical or biological need, and our needs are certainly not all evaluated against the criteria of survival. That does not, however, ease the demands. So it is useful to consider once again the concept of "limits to growth" in the context of environmental resilience.

Three environmental concepts can be used to test the idea of limits to growth. These are carrying capacity, outer limits, and irreversibilities. To achieve a synthelithic existence, we will need satisfactorally to resolve problems emerging under these headings.

Aldo Leopold defined carrying capacity as a saturation point where the number of a particular species of grazing animals approaches the point where grasslands can support no more individuals without a general and continuing decline in the quality of the pasture land. Thus, carrying capacity means a unit of land's ability to support a species or some optimum mix of species, each occupying a niche in the grasslands. It is a concept of pasture management. To generalize the concept requires the assumption that we humans are the grazing animals, occupying, at this time in evolutionary history, a worldwide niche. We are all involved in pasture management on a worldwide scale, albeit confined in a narrow climatic valley.

An obvious scenario to stay within a naturally driven carrying capacity is to copy a major practice of nature, that is, population limitation. In our case, or at least we hope for the condition, human population would be limited by intent rather than by natural cycles.

Another obvious scenario is to use a site intensively until resources are depleted and then to move on -- to slash, to burn, and to move into the next valley. To the extent that resources are naturally renewable, it is possible to return to the original site years, generations, even centuries later. This strategy, obviously, requires open frontiers.

Yet another scenario is to change the carrying capacity technically by adding inputs from outside the pasture, outside the valley where we live, by controlling competition in the trophic structure (widening the niche of economic species and therefore of humans) and by improving the efficiency of the use of available resources.

If we opt for the third scenario (and we seem fully committed to it now), it becomes obvious, early on, that we are dealing with single variables that could limit growth -- in other words, critical resources. Water, although massively abundant on the earth, becomes a critical resource if the environment is relatively arid or if there is a drought. We know that there is water, water everywhere, but it has to be clean and at the right place at the right time. In another situation, phosphates as plant food are limiting. Phosphates were naturally deposited in limited and often inaccessible areas of the earth. But there is a need for them in every pasture and in every grain field. Almost all resources are potentially limiting.

To resolve this issue of critical and limiting resources, it becomes necessary systematically to control increasing numbers of the resources and the variables that influence their availability until we have a tightly constructed system -- or to move away from "natural" resources.

With whatever carrying-capacity scenario we adopt, it becomes inevitably necessary to monitor the environment for the impact of the pollution we generate and to "improve" the environment's ability to dilute pollution. Pollution is, of course, another of those strictly human concepts because humans insist on placing themselves in the center of things in assessing benefits and

costs. It is *our* benefits and *our* costs that almost always concern us. Pollution is pollution only when it adds to our costs. Rarely do we consider those costs to nature in general.

We don't have to settle for a single carrying-capacity scenario. We could limit population, move to new sites, apply technology, and effectively control pollution. But we would then stop somewhere short of a truly synthelithic existence. Thus, the "industrial" interlude.

A second major environmental concept useful in testing the idea of limits to growth has to do with nature's outer limits. Are there any really limiting factors, short of the oxygen supply, worthy of economic consideration?

Parameters of natural outer limits can be expressed in terms of natural environmental fluctuations and natural catastrophes leading to a drying-up of resources. Such conditions or events may be "local" or, perhaps, global.

In the 20th century particularly, we have relied upon "natural capital" for much of our explosive expansion: rich concentrations of mineral ores, loess soil deposited deep by winds off the face of a continental glacier, virgin forests unswept by fire for 400 years, annual rainfall and fossil groundwater, and, most important, fossil hydrocarbons.

As the richest of such sources have been exploited, we have turned to less-concentrated deposits, that is, to resources more randomly dispersed in the environment or more tightly locked in chemical bondings. We continue to require resources of high quality, so we improve the quality technically from sources that are increasingly randomly dispersed or more tightly chemically bound by expending increasing amounts of energy. Thus, technology *per se* is not the answer. Available energy is also needed.

It is even possible that our current confidence in technology is misplaced, that there has not been a truly valid test of its viability, because we have been drawing on high-quality, natural capital.

The technical optimists assert that the world contains plentiful retrievable resources that can supply humankind with the necessary materials for the very long term and that these resources can be extracted and converted to useful forms indefinitely with acceptable environmental consequences and within the boundaries of forseeable economic constraints.

But there are some conditions beyond minerals and energy. The principal requirements to achieve this goal of "infinite natural resources" are stable political conditions, a continuing availability of capital, and vigorous and successful research in the materials sciences. Because critical resources are not uniformly distributed even in low-quality reservoirs, this scenario indeed calls for world order on a scale not heretofore experienced. That would be achieved by broad enlightenment, immense voluntary obedience, or a truly "infallible" marriage of state and technology. Open-ended scientific pursuit, which can rattle bureaucratic cages, seems to be fundamentally at odds with such a condition of absolute determinism.

It is not possible to draw a theoretical outer limit on a map for the future like a cartographic, political boundary. But it is possible to *imagine* an outer limit, a kind of diffuse, stochastic band. In fact, such bands may be the most common boundaries that have delineated the history of human societies and of civilizations in less demanding ages than ours.

Natural outer limits are describable and measurable. Several of them are signally important. Climate is the most obvious -- ranging from diurnal to lunar, to seasonal, to decadal cycles of wet and dry or hot and cold, to glacial and interglaical, and to climates

framed by the monstrous but slow-moving changes of plate tectonics and the location and form of the continents. It is obvious that human experience on earth ranges over glacial to interglacial with an ambient temperature change of around seven degrees centigrade.

Such variations cause striking biological responses on a global basis. Within the 50,000-or-so years of a glacial cycle, the climate probably flips from pre- to postglacial well before the freeze or the thaw. Historians speak with some awe of the "little ice age" in the 11th to 13th centuries. Nature may have misled humans because of a "temporary" warming after the last glaciation. We don't have a written history of the conditions in the thousand years or so leading up to the last glaciation, although intelligent humans were almost certainly out there on the steppes, smelling the cooling wind. Maybe major glaciations send out a series of erratic signals, a series of 200-year cold blips, before really settling in. And maybe we have also been forewarned.

Natural catastrophes range from earthquakes and volcanic eruptions, with local impact usually, but not always. Single, massive volcanic eruptions can affect climate for years and perhaps decades. There is historic evidence of a "year without a summer." More interesting would be a collision between earth and a mountain-sized meteorite and the monstrous impact that would have on climate.

While our current capabilities of predicting weather and climate are quite feeble, the fluctuations are clearly physical, perhaps even mechanical. They are somewhat less than random and probably cyclical. We have considered technical modification of weather and climate but only on the modest and local scale, for example, by wearing clothing and constructing houses, with some feeble and unsatisfactory attempts at rainmaking. For a synthelithic existence we must, however, go much further. If we really want that existence, we must, it seems, learn to control climate, more specifically, to control ambient temperature and precipitation. Not just with air conditioners and irrigation, but with delimited seasonal norms and rainfall. We would need to figure a very specific way out of the narrow climatic valley in which we have always lived. Above all, we would need to learn how to forestall glaciation.

Earth's geomorphic processes also are expressed in environmental fluctuations related to basic processes of gravity, fission, and fusion and the heat energy they generate, but we usually think of these changes on a time scale that is scarcely economic. Occasionally, we try to control earth's natural "background" radiation, such as the generation of radon gas from natural fission and the habitat limitation it causes.

The movement of continents, mountain building and destruction, the opening and closing of oceans, the ephemeral nature of lakes and rivers, and the migration of the earth's poles and the equator leave us fascinated but not usually rushing to the bulwarks of technology to change such things, although we have seriously proposed reversing the courses of rivers on a continental scale as an aid to precipitation. And we are actively engaged in river-flow augmentation. We might decide to excavate continental networks of canals on a Martian scale. In the mean time, in our own back yards, we are having a hand in such processess by acclerating erosion. But this takes us in a direction opposite to the one in which we want to go. For a synthelitic existence we would need to accelerate these geomorphic processes, specifically those that concentrate minerals, perhaps by low-energy distillation of seawater.

That leads to a discussion of another fundamental environmental fluctuation to consider in our evaluation of outer limits. That is the natural cycling of elements in the environment, for example, the cycling of carbon, which is the most reactive of all elements.

Carbon shows up, pure and vibrant as an October morning, in the form of a diamond. Combined with oxygen, it is a gas, carbon monoxide or carbon dioxide. Combined with water water, it is a carbohydrate. Reduced from that, it is a hydrocarbon. It may also be locked away for eons as a carbonate in earth's vast sedimentary graveyards.

More important is the fact that there is a carbon cycle. And an oxygen cycle. A nitrogen cycle. And a phosphorus cycle. All of these elements and more are essential to our existence, whether that existence is technological or not. But here's the real issue: In some forms the elements are relatively available and useful. In other forms they are not so available and sometimes deadly. They are useful or harmful to us, and the positions they occupy in the cycle affect our habitat.

When biology is introduced, the cycles become a spiral that interweaves physics, chemistry, and life and that *progresses* from the past, through the present, to the future. The spiral is microscopically molecular and macroscopically worldwide. The current abundance of free oxygen is necessary for advanced life. But the abundance of oxygen is also a product of the long reaches of life. We have come to our current existence via the oxygen cycle-spiral. Our future is framed by the history of that spiral.

To intervene in a technical way in the cycles and spirals of elements requires an understanding of where we have come and where we are going and whether we are causing a fundamental deviation, even moving into a danger zone. Haphazard intervention that dissipates the stratospheric ozone blanket could recycle life back to a point 3.5 billion years ago, when ultraviolet light, penetrating to earth's surface, was a dominant outer limit. It seems clear that we need to manage, indeed, control, the carbon cycle. And control means more than controlling discharge rates. It means regulating the optimal level of carbon dioxide for optimal chlorophyll activity but not for excessive warming. In other words, we need a controlled global greenhouse.

To fully understand environmental fluctuations and the case of outer limits, we must also consider one more natural process -- the most remarkable and complex of all. That is the phenomenon of ecosystems.

The environment and time obscure the death of an individual and even the extinction of species like ripples disappearing from a mill pond. But the death of an individual or the extinction of a species is not without infinite reverberations and change. Individuals and species generate echoes. The individual does matter in the long course of events. That is because of the spiraling cycle of evolution and the fact that every individual is a potential link in the chain at the moment of reproduction, but it is also because of ecosystems and the structure and the continuity they bring.

The ecosystem is the conceptual unit of biological organization. It is all the organisms in a given area and all their interactions with each other and with the physical environment, including energy, so that a flow of energy leads to nutritional pyramids among species and to material flows within the system.

What we see, holistically, is a fluctuating, pulsing web in which each unit affects the others and each "decision" affects the process. The ecosystem becomes a kind of neighborhood mat of neurons, a neighborhood brain. We cannot reach in and delete either an individual or an episode without affecting the others or destroying memory. Such an impact may be miniscule or monumental, but that is not really the important point. Individual "brain cells" may die or become damaged, but ecological memory and reason are a function of all the cells. So it is the web that is important, coupled with the fact that we -- even we -- are imbedded in the web.

Once again we find ourselves in the middle ground. But this time our being in the middle ground is not contrived in a medieval struggle between church and science over geocentrism. It is a natural middle ground for which we search. At the same time, every other living thing is also in the middle. And the inanimates are also in the middle. Here, in the middle, our little spaceship earth is as isotropic as the universe. No matter where you are, it is the same in every direction. How far can we move from this middle ground?

Can we move from it at all? Is Eden isotropic? Are we chained in place forever?

There *are* outer limits in ecosystem stability terms, and we do begin to see the boundaries. So we are tempted to *fix* our position in the middle, that is, to stabilize a global ecosystem designed around our ends. The most difficult issue we would face is whether we would also fix the evolutionary life spiral. We could get to the point where improvements would seem too risky.

Some of the early myths about Eden describe our departure as a break for freedom. But there is the possibility, considering our environmental boundaries, that there is as much freedom within Eden as without.

Before we decide, we must also face up to the issue of irreversibilities. Bluntly put, this is the river of no return -- at two levels. The first is an irreversible shift in the environment that would change the course of nature on earth out to the end of earth, to that time when the sun turns swollen and red and the earth vaporizes. We can look at our nearest neighbors, Venus and Mars, and see two scenarios for interim, global environmental change. Venus is a runaway greenhouse, and Mars is frozen to near immobility. We don't know if these two planets evolved away from an environment favorable to life, and it seems unlikely that either of these planets would evolve back to a favorable habitat for life.

But nature is complicated, and who knows? There must be other scenarios for planets, including the scenario being played out on earth. There may be conditions more favorable to life than the one in which we are embedded. We could imagine an only slightly modified earth without any life. But then, earth is well experienced in that condition. In fact, there is enough time in earth's history for life to have emerged, grown sophisticated, and disappeared, then to have emerged again later, with perhaps a billion-year interval. Or two billion years. Maybe advanced life forms come and go like periods of glaciation.

The second irreversible condition of interest is somewhat more narrow in perspective. It is the death of a specific living individual, or of a species, or of an era of species. Death and extinction *are* irreversible for the individual or for the species.

So what are the conditions that generate death and extinction?

Given an understanding of geological process and of biological evolution, we tend to think of change as the *slow* process of aging and of re-creation. The conditions described under outer limits can lead to irreversible changes.

But we know, if we are observant, that massive intervention does occur, and as we study it, we find that much of the change occurs in short and violent episodes: storms that occur once in a hundred years, earthquakes and landslides, floods at the end of glacial epochs that change the chemistry of oceans, firestorms, volcanic eruptions, intermittent kilometer-sized meteorites, even, perhaps, nearby supernova explosions. Such natural interventions have at least the potential to send shock waves through a previously benign environment and to eliminate the more "satisfied" of the species extant at the time. Is there a possibility of technolgically controlling these massive interventions, or must we be fatalists?

We now recognize the existence of these episodes down through time and, because we haven't completely kicked our addiction to risk, may even secretly hope that we will witness such an event in our lifetimes. Perhaps they are nothing more than side shows in our analysis of irreversibilities. But then, it dawns on us that we may ourselves unwittingly set in motion such a sudden catastrophe and be ourselves caught up in its vertigo.

The concept of irreversibilities is rooted in basic physical laws involving thermodynamic perspectives and time. Although nothing at the level of matter and energy is destroyed, free and available energy does inevitably degrade over time to latent and unavailable energy. Thus, the concept of entropy.

We would need to understand the level of available-versus-unavailable energy on a truly global basis to predict an irreversible change in the earth's energy balance leading to a frozen ball in space. But if we have the capacity to influence it, we ought to have the cleverness to monitor what's going on and to prevent it.

Negentropy (order) is the counterpoint to entropy. A high state of negentropy is rare in the vast reaches of the universe and the long reaches of time, although we are aware of the trillions of stars, and we know that new stars are being created much more frequently than previously thought. So, presumably, are planets. So, too, presumably, are the conditions for, and actuality of, life. Negentropy (including the condition of intelligent life) is repeatable, possibly even replicatable, possibly even clonable, because existence is proof of existence.

Humans have managed to dip deliberately into the pulse of entropy and negentropy -- breaking into the waves of energy and constructing complex organizations -- but we have not broken down the waves. They still come crashing over our heads, driving us onto our knees in the sand. Ours is, in fact, an act of precarious, surf-board balancing, requiring skill and concentration, a sense of timing, an understanding of when to get on and when to get off, depending on the size of the wave and some degree of luck. Being deliberate about it does not necessarily make it easier because the waves are generated across the oceans of space, far from arm's-length.

It is not possible, at least so far as we have conceived, to reverse the basic process of entropy in larger than a very local scale -- to run it backwards. Entropy seems bound to the unidimensional time in which we, on earth, are imbedded. To believe we can change it technologically seems, at least so far in our journey, arrogant.

It is possible to understand what came before, what freed the photons and sent them on their way. We see the light this evening from ancient fires near the time of the universal creation. It is also possible for our technical process to structure matter the same as a previously attained phase, on a local and temporary scale, when there is a relatively abundant supply of available energy, when a larger-than-normal wave washes up on our beach. We can build and tear down modest mountains but cannot, at least yet, move continents.

It is also abundantly clear that complex organization is not really our creation. It develops naturally. Witness concentrations of rare and heavy metals, witness living organisms, and witness the ability of one species (but only one species) to comprehend complex organization.

But it is also clear that natural processes inevitably disassemble complex organizations. Witness the extinction of species. Witness the San Francisco earthquake. The history of the earth is full of such events, of catastrophic turning points and monumental discontinuities. Irreversibility becomes the most basic of natural phenomena. It is likely that the very early successes of the complex DNA molecule outcompeted other basic complex forms that could have

led to an alternative structure of life very different from ours before DNA became the singular model for all life as it currently exists on this planet. Maybe the energy wave caught by early forms of DNA came at a fortuitous time for DNA.

It is also clear that humans can disassemble complex structure -- with intent, because we do not value a particular structure, or heedlessly, because we do not recognize its value. Finally, it is apparent that we have hastened irreversibility; we have accelerated the entropic erosion. So the inevitable existance of irreversibility is the basic process that delimits the future of more elaborate processes. And it has a strong element of fortuity, of timing. And the conclusion becomes inevitable. The question must be asked: For a synthelithic existence, do we seek to reverse irreversibility?

The premise is that the 20th century stands unique among the valleys of time. That's a heady thought, if true. Assuming that the earth is four billion years old, there have been about 40 million centuries from which to choose one that is unique.

Our understanding of science and its concomitant technology, for the first time, gives to one knowing species the ability to influence in fundamental ways the natural course of events. Humans obviously have influenced the environment for some 20,000 to 40,000 centuries out of the 40 million since the beginning of earth but not, simply not, on such a monumental scale as in the 20th century of the four-millionth millenium.

Science and technology have enabled us to accelerate the rate of change, but with only limited understanding of the cause-and-effect relationships that economic expansion has superimposed on natural growth. A synthelitic existence requires monumental understanding of the relationships.

Perhaps we can confidently reject the concept of limits to growth that has operated for those millions of millenia in natural processes. Until we know more of that, until we have a clearer understanding of the relationship between time and growth, there are some questions we should force upon ourselves. They're not millenial questions, just little, pragmatic ones -- the kind with which our forum speakers struggled:

> Under what combination of conditions would expansion (planned economic growth) be naturally limited by depletion of resources, by scarcity of critical resources, by irreversibilities?
>
> Under what combination of conditions would expansion be limited by ineptness in bringing together the array of renewable and nonrenewable resources, particularly energy supplies?
>
> If catastrophes caused by our commitment to expansion are a consideration, will they likely be geographically local (regional starvation) or suddenly global (carbon dioxide balances)? Will regional problems spread globally (a spread in patterns of starvation due to population increase, desertification, and carbon dioxide's impact on climate)?
>
> Will the course of expansion, together with the recognition of limits and risks, lead us to a pattern of increasing regulation? With regulation, what are we giving up in this monumental century of bargaining with nature? Are we giving up freedom of independent action and, therefore, self-interest?

There are no generally accepted answers to even these questions and no detailed scenarios to deal with the answers. But we seem bent on forcing the questions. The 1987 summer forum was an attempt to get going.

Development Pressures on the World's Peasants: Environmental Trends and Development Lessons from the Bottom Up

Timothy C. Weiskel

> . . . the last thirty years have been the most disastrous in the history of most, if not all, Third World countries. There has been massive deforestation, soil erosion, and desertification. The incidence of floods and droughts has increased dramatically, as has their destructiveness; population growth has surged, as has urbanisation, in particular the development of vast shantytowns, in which human life has attained a degree of squalor probably unprecedented outside Hitler's concentration camps.
>
> With such developments have come increased malnutrition and hunger; so much so that today we are witnessing, for the first time in human history, famine on a *continental scale*, with two-thirds of African countries to some degree affected.[1]

Voices from the Periphery

After nearly 30 years of post-colonial government in most of Africa it is sobering to listen to the discourse African villagers use to discuss their contemporary circumstance. Consider, for example, the concept of "independence." Most of the villagers I worked with in the Ivory Coast were born since the violent incidents of the nationalist struggle in the early 1950s, and many have lived their whole lives under *l'indépendence.*[2] Clearly, for these people the word cannot include the same range of associations as it does for those who knew colonial rule as adults and struggled to free themselves from it.

Each year *l'indépendence* is commemorated in a specific holiday, but for these younger people it has come to mean not so much a glorious achievement or a liberated state of affairs but rather a past moment in the history they are taught about in school and reminded about through the promulgations of the state religion. The state seeks to cultivate continued reverence for those who won independence from the French by commemorating the struggles, but there is little explicit discussion of what *l'indépendence* is supposed to mean except in terms of exhorting the population to greater and greater levels of voluntary hardship and sacrifice. For those who did not experience these struggles, the whole concept of *l'indépendence* can understandably be viewed with a tinge of resentment.

Whatever it may have meant for the nationalist leaders, the party militants, or the actors in the international arena at the time, *l'indépendence* is referred to now by many younger villagers in the Ivory Coast in somewhat ironic tones. It is something that happened once upon a time. It was no doubt "a good thing" for some people, but others are not so sure since they have not benefited in equal measure from *l'indépendence*. In any event *l'indépendence* was an episode; it is past, done with, finished. In retrospect it seems to assume the functionally equivalent symbolic role of war stories in European cultures. It is a positive, living reality for an ever-dwindling portion of the population, while for others it has become a synonym for a perhaps glorious moment that in any case cannot be retrieved. What remains among the youth is a disillusionment bordering on cynicism: "So this is independence? Heh!" [*C'est ça, l'indépendence? Eh bien!*]

Discussions of "development" are similarly revealing and sometimes troubling for anyone who has spent time trying to improve the welfare of rural populations. In French-speaking areas several euphemisms surrounding the concept of development abound. During the 1960s it was

common merely to import the word from English: "development" became *développement*; "developed countries" became *les pays développés*; and "underdeveloped countries" became *les pays sous-développés*. In polite, liberal circles it soon became unfashionable to refer to large portions of the world as *sous-développé*, so French speakers coined a more gracious expression, referring to the former colonies as *les pays en voie de développement* -- that is, "countries in the process of development," or perhaps more simply, "developing countries."

All of this may well have been quite useful for expatriate development experts who needed to offer justification for their presence and boost their own morale in the face of evident and persistent failures, but the discourse, once appropriated, began to have a life of its own among peasants in the villages. Phrases like *développement, sous-développement, en voie de . . .*, etc. all got turned around in local consciousness and came to mean something quite other than what they were meant to convey in the expatriate communities or government bureaucracies. As circumstances began and then continued to decline for rural populations, some Ivoirian peasants began to refer to their country not as a "developing country" but rather as *un pays en voie de sous-développement* -- that is, "a country in the process of underdevelopment," or more simply, "an underdeveloping country."

The phenomenon of pervasive and irresistible change is recognized in this usage, and furthermore this change was closely associated with what the bureaucrats have called "development" projects. Still, in some cases the subjective valuation of the whole experience from the villagers' point of view is totally opposite from that imagined in government and foreign aid circles. Once again ironic tones predominate: *C'est ça le développement? Eh bien!* If there is direction or momentum to the process it is often understood to be more associated with decline than with improvement in local circumstance.

As transistor radios in the villages blare forth the news of economic recovery in the Western world's major economies and the simultaneous growth of Third World indebtedness, the experience of living in *un pays en voie de sous-développement* [a country in the process of underdevelopment] becomes all the more an inescapable reality. Initially coined in a joking manner, such a phrase has come to reflect the embittered consciousness of many of the world's peasants. Whatever "recovery," "improvement," or "development" is taking place in the world at large, so the feeling goes, it is being accomplished at their expense.

"Development" and Environmental Degradation in the Third World

The subjective feelings of exploitation are mirrored in objective measures of environmental and economic circumstance at the village level in large portions of the Third World. While it is perhaps most convincing to witness these trends in the field, their reality should be apparent from a sensitive reading of available figures and reports that deal with aggregate populations or macro-level change. Several well-documented environmental and economic trends are of particular import to the world's peasantries.[3] These include problems of deforestation, the expansion of petrochemical agriculture, the shift in weather patterns and perhaps climate in the semiarid areas, continued population growth, and the penetration of local food markets with Western food supplies through surplus dumping or foreign aid.

One of the most familiar among the measured environmental trends in the Third World is the phenomenon of tropical deforestation. While anthropologists have observed this on a microecological basis for several decades, it is now becoming measurable from satellite monitors in space. The scope of the transformation is massive. In March 1984 the Office of Technology Assessment (OTA) reported to the United States Congress that deforestation in tropical areas was proceeding at an alarming rate: "Each year approximately 11.3 million hectares (4.57 million acres) of the Earth's remaining tropical forests -- an area roughly the size of Pennsylvania -- are cleared and converted to other uses," the report indicated.

If current trends persist, the report makes clear, much of the earth's tropical rainforest will be gone by the turn of the century. It estimates that at current rates, "Nine tropical countries would eliminate practically all of their closed forests within the next 30 years and another 13 countries would exhaust theirs within 55 years."[4] Attempts to reforest denuded areas have been made, but estimates are that reforestation efforts affect only about one-tenth of the area deforested at the current time.

Deforestation occurs in all of the tropical regions of the world. Nations experiencing the worst deforestation include the Ivory Coast in West Africa, where 6.5 percent of closed forests are lost each year; Nigeria in West Africa, 5 percent; Paraguay in South America, 4.7 percent; Nepal in Asia, 4.3 percent; Costa Rica in Central America, 4 percent; and Haiti in the Caribbean, 3.8 percent.[5] The OTA study joins a chorus of others that have been published recently, for efforts to publicize the fate of tropical forests have been made by scholars and researchers for several years.[6]

As scientists are informing us, the tragedies involved in the loss of tropical forests are far greater than the hardships these losses impose on local peasantries or isolated ecologies. Indeed, the impact of tropical deforestation is global in scale for three main reasons. First, the tropical rain forests are perhaps the greatest remaining store of biological diversity left on the planet. Second, these ecosystems play a major role in the biogeochemical cycling of carbon and the earth's atmospheric gases. Third, and partly as a result of their role in the biogeochemical cycles, the tropical rain forests appear to play an as yet unclear but nonetheless important role in the regulation of the earth's climate.

Despite the volume of already-published scientific studies and others underway that warn against the dangers, the pattern of deforestation has not been noticeably reversed by acts of policy in recent years. Third World countries involved in the process of forest loss are by now genuinely concerned about this form of ecological degradation, but they are frequently impotent to do anything more than monitor what has occurred. In 1987, for example, an environmental group known as The Mexican Ecological Movement indicated that: "The unplanned cutting of timberland in the past 30 years has caused Mexico to lose 45 percent of its forest reserves . . . in 1957 Mexico had 3 million acres of forest, compared with some 1.8 million acres of current wooded lands."[7] Much of this forest loss is not of the same kind that has occurred by explicit timbering of tropical forest reserves, but the resource loss to peasants is nevertheless real and dramatic.

In some cases, localized patterns of deforestation can cause national and potentially international complications. Deforestation in the Himalayan highlands has been seen to be linked over time to the pattern of flooding downriver in Bangladesh. In addition, the process of deforestation currently proceeding in Panama seems to be affecting not only peasant welfare and local agriculture but potentially the integrity of the canal passageway itself. A report issued to the government of Panama indicated that the canal's most pressing problem is that of deforestation. In 1952, 80 percent of the Panama Canal basin was covered with forest, while today only 20 percent remains forested. "The jungle is being deforested at the rate of 5,000 acres per year," the report indicated.

The loss of forest cover on hills and mountains allows soil to be washed down into the lakes and connecting waterways, causing siltation. The Panamanian government report estimated that this process was expected to reduce the Panama Canal's capacity by 10 percent in the year 2000. The report, coordinated by Stanley Heckadon Moreno, an environmentalist at the Planning Ministry in Panama, stressed the urgency of acting immediately to reverse current forest-loss trends. "We believe," the report authors said, "that unless corrective measures are taken immediately, the basin will be totally deforested and the useful life of the canal will be reduced to less than 25 years."[8]

As the Panama circumstance indicates, many of the causes of deforestation are to be found in the desperation of landless peasant families seeking new territories for farming. UPI reporter Elizabeth Love summarized the situation in these terms:

> A steady stream of landless peasants has been invading the land around the canal. They earn a meager existence by raising cattle and raising crops by using slash and burn agriculture, both activities that destroy trees and native plant life that protect the soil. Some 40 underequipped forest rangers patrol the 1,280 square miles that make up the canal watershed, but stemming the tide of migrants and persuading the farmers to move on is difficult.
>
> [If] the government simply tells them by means of the armed forces or forest rangers, 'You can't cut the forest,' the peasants perceive that as you saying, 'You can't eat,' said Heckadon Moreno. He said some 50,000 peasants already live in the canal basin area and the figure is expected to grow 7 percent annually. If peasants are not offered an alternative in the way of jobs or land, "political restlessness" could further hinder canal programs, Heckadon Moreno said.
>
> Just the other day, 50 or 60 families created a situation in which weapons had to be drawn [to evict them]. What are we going to do in five years time when we have mass amounts of people there demanding land?" he said.[9]

While deforestation in Panama and in many African countries may be the collective result of individual actions undertaken by small household peasants, elsewhere it seems to result from explicit policy decisions for development projects proposed by corporations or national governments and supported by the international financial community. Environmental groups like the Rainforest Action Network and the Tropical Forest Action Group have directly linked the loss of forest resources to the types of development strategies pursued by nation states and financed by the World Bank.[10]

Randall Hayes, director of the Rainforest Action Network, indicated at a conference in Boulder, Colorado, in February 1987 that he intended to wage a campaign to arouse public opinion against the international financing of development projects that had the direct or indirect effect of destroying tropical rainforests. Pointing out that international financial backing is required to launch many of the cattle ranch and agriculture development projects that have a direct impact upon the tropical rainforest, Hayes argued that if the flow of supporting capital could be stopped, the rate of deforestation could be slowed. "It's a battle that can be won . . . ," he said, "It takes money to finance this destruction. If we can stop the money, we can stop the destruction."[11]

Other protests against World Bank development policies have taken more direct action. Last September members of the Tropical Forest Action Group were arrested as they demonstrated against World Bank policies by unfurling a 40-foot by 20-foot banner from an 11-story building near the World Bank headquarters. The banner read simply: "World Bank Destroys Tropical Forests." It was meant to be seen by finance ministers and world economic policy officials as they met in Washington to discuss future lending policies of the World Bank. More recently, adverse publicity for the bank's policies has focused upon the ecological devastation that bank lending helped engender by helping to finance extensive highway construction in the Amazon basin.[12]

If changing the consciousness of international finance organizations is sufficient, there may be some room for optimism here. At the highest official levels, at least, there seems to be an emerging consensus that something must be done. Perhaps in response to increasing accusations that it has been bankrolling environmental destruction or in response to its own internal policy review, the World Bank announced intentions in May of 1987 to give environmental

concerns top priority in future lending decisions. World Bank President Barber Conable indicated, in a speech to the World Resources Institute in Washington, that explicit efforts would be made in the future to halt the spread of deserts in Africa. "The World Bank is a force for development and will remain so," he said. "Our role in such projects, however, will include greater sensitivity to their long-term environmental effects. And we will put new emphasis both on correcting economic policy incentives that promote environmental abuse and on stimulating the small-scale activities that can combat human and environmental deprivation."[13]

The remaining questions are simply these: Is this kind of gesture too little, too late? Even with the best of intentions can large international organizations like the World Bank effectively reverse a pattern of Third World decline that has been under way for over 30 years? Is there not a fundamental contradiction between environmental conservation and "development" as it has traditionally been conceived? Environmentalists are beginning to phrase the question in just these terms: "Is development the solution or is it the problem?"[14]

The issue of tropical deforestation may prove to be the weather-vane case. The World Bank intends to raise its funding from $138 million to $350 by 1990 for studies to preserve tropical forests. Moreover, it recognizes the need to fund projects that promote conservation, but it may well be that projects of this kind would require flat opposition to "development" programs that have been launched and are likely to continue in the Third World. In any direct confrontation between the newly informed consciousness on the part of World Bank donors and the entrenched special interests advocating conventional forms of trade, aid, and development in the Third World, it is not clear that the newly discovered environmental sensitivities of World Bank officials will prevail. Indeed, there are mounting signs that the policies of development that have caused the most rapid and irreversible forms of environmental degradation are likely to endure. In fact, these policies are likely to be applied in an accelerated manner in the coming years, despite the best intentions of the World Bank's officials.

The Dynamic of Environmental Degradation: The Underdevelopment Spiral

The reason for this can be located in what might be called most generally "the underdevelopment spiral." This is a syndrome of interrelated social, economic, and ecological phenomena that together engender a self-perpetuating cycle of environmental decline. As these phenomena interact, they reinforce one another in a synergetic manner, accelerating a spiral of decline and making it increasingly difficult for any one party to intervene to arrest the process.

To clarify, then, why shifts in World Bank policy are not likely on their own to be sufficient to change conditions in the Third World, it is perhaps useful to outline the elements and interactions involved in the underdevelopment spiral.

The elements of the syndrome are straightforward. They include:

- -- the expansion of cash-crop agriculture in the Third World;
- -- the secular decline of real prices of Third World commodities in world trade;
- -- the growth of cash exchange, collapse of local artisans, and expanded merchandising of European manufactured goods;
- -- the decline of small-hold agriculture and increase of "landless peasants";

-- the movement of Third World populations from rural to urban areas;

-- the overall demographic expansion in Third World populations;

-- the industrialization of agriculture and overproduction of crops in industrialized nations;

-- changes in local weather and microclimate patterns;

-- local and regional food shortages and the growth of international food trade and aid;

-- destruction of agricultural or pastoral lands through overgrazing, loss of topsoil, salinization, flooding, and waterlogging;

-- the fitful but secular increase in the price of petroleum and petroleum products;

-- the long-term increase in relative prices of manufactured goods;

-- the growth of Third World indebtedness; and

-- the expansion of bureaucracies, the collapse of public services and the growth of corruption.

Added to this is a further set of elements that are not present in every Third World circumstance. When they are, however, they tend to accelerate the pace of the spiraling interaction of the above elements. These added elements come into play when peasantries seek to arrest the underdevelopment spiral and take matters into their own hands. Typically this involves attempts to: (1) seek to resist direct government exactions in one form or another, (2) seek better trade terms for items they produce, or (3) seek control over arable land in order to pursue autonomous farming. If these peasant movements are countered by the state or by other classes acting on their own, the following added elements can come into play:

-- escalation of conflict in rural areas, diverting efforts from agricultural production;

-- growth of an international arms trade, causing further drains on foreign exchange;

-- outright destruction of crops, villages, and ground cover; and

-- ground combat, bombing, chemical defoliation, or purposeful torching of biota to destroy an opponent's means of securing shelter, food, or a livelihood.[15]

These latter elements are usually present only in extreme circumstances where the former elements have reinforced one another for years, decades, or generations. For general purposes, therefore, it is possible to set these obvious cases of environmental destruction aside for the moment to concentrate on the former elements and examine how they interact to produce the steady and seemingly irreversible cycle of environmental decline in the Third World.[16]

The first thing to note about the interactions between the elements is that although they are presented above in a specific order, no particular order is needed. Each element reinforces the aspects of the other elements in cyclical and perpetual interaction, approaching what systems ecologists might call a "positive feedback" mechanism. This means that analysis can begin with any element and proceed through all the others. The links between them all

strengthen themselves as the elements become more pronounced. Different academic professions will, no doubt, choose different points from which to start analyzing the links between the elements. Thus, economists may wish to begin by talking about the declining price of agricultural commodities, whereas a demographer might begin with the population explosion, while a sociologist starts with Third World urbanization patterns. Soil scientists will probably talk of wide-scale erosion, while ecologists might well begin with the massive transformation of the agricultural landscape, and journalists might choose to focus on massive corruption or bureaucratic incompetence.[17] Because all of these processes are going on simultaneously in a self-reinforcing manner, just where one begins the analysis of connectedness is not crucial to understanding the underlying dynamic of the whole process so long as the interaction of all elements is kept clearly in mind.

Postwar Africa: A Case Study in Ecological Devastation

To provide a brief illustrative narrative of how the phenomena are linked, we can begin with the post-World War II expansion of cash cropping in the Third World. Throughout Africa and much of the rest of the Third World during the colonial period, rural regions became accustomed to imported manufactured goods that had become essential for their households or their agricultural pursuits. Axes, machetes, hoes, pots, cotton cloth, and sundry petty manufactured goods from matches to kerosene lanterns had penetrated rural regions during the early years of colonial rule. At the same time, these regions had become accustomed to producing agricultural commodities like peanuts, coffee, cocoa, and cotton to earn the money to purchase these petty manufactures.

During the war, however, two simultaneous phenomena occurred. First, the supply of European manufactured imports was cut off by scarce or nonexistent shipping under wartime conditions. This raised the price of imports considerably, and for some time many goods simply were not available at all. The need for the goods upon which local households had come to depend remained pronounced, however, and in the process a considerable pent-up demand began to grow for European goods throughout the Third World. The second major phenomenon, again due in part to wartime stringencies and problems of shipping, was that agricultural commodities produced for sale exceeded shipping capacity, and thus their prices dropped in local markets. These combined phenomena created considerable pressure for change in colonial economic circumstances in the immediate postwar period.

With the removal of the wartime shipping problems in the late 1940s and 1950s there ensued a period of economic expansion unprecedented in colonial history. The colonial administrations usually contented themselves with building roads and other public works while maintaining public order, but apart from these roles they needed to do little positive planning to encourage economic growth in this period. The pent-up peasant demand for manufactures and their capacity to expand their own production to earn more cash for these purchases were in themselves sufficient to enable most colonial regions in Africa to witness a remarkable trading bonanza fueled by the rapid cash-crop expansion.

The cash-crop boom, although sustained for several years, remained nevertheless an inherently unsustainable phenomenon, ironically because of its very success. So many peasants in the Ivory Coast, Ghana, Nigeria, and the Cameroons turned to cocoa and coffee production that the mounting supply was exceeding world demand, and the prices of these commodities began to fall in real terms during the 1950s. As Brazil and East African countries like Kenya entered the ranks of coffee and cocoa producers, the purchase prices of these commodities declined even further.

This engendered the classic syndrome known to economists as the "primary producer's squeeze." The dilemma went something like this: Oversupply was at the root of the declining purchase price for these commodities, and it could be argued that the peasants should refrain from producing further cocoa or coffee or the like until the supply declined and the prices came up to a level of their liking. While this might be a theoretical possibility, in practical terms it was never really an option for most peasants.

The reasons for this were simple: peasants had already made the infrastructural investment in the cocoa and coffee plantations. The trees could not simply be turned on or off like a faucet when prices proved favorable. On the contrary, these commodities were harvested annually and would be wasted entirely if not sold within a fairly short time of the annual harvest. If the weather and pest problems were manageable and a region experienced a particularly good production year, they were faced with the irony of a locally glutted market at harvest time and a correspondingly depressed purchase price. In the face of a depressed price, a peasant with fixed or escalating costs or other demands upon his income had basically two options open to him. Either he could chose to expand the scope and scale of his production to maintain or enlarge his income to meet his growing needs, or he could leave cash-crop farming and go to the city in a hopeful search for nonagricultural work. Such was the squeeze most peasants faced in one form or another.

A third option -- that of engaging once again in foodstuff agriculture -- was largely precluded at the time by the impact upon Africa and other Third World areas of the pattern of agricultural overproduction from the Western countries, particularly the United States. In the postwar era, United States farmers began to mechanize agriculture, purchasing tractors, fertilizers, and pesticides to substitute for the declining manpower engaged in on-farm production. The initial results of this petro-subsidized agriculture were very impressive in volume output, and since oil prices at the time reflected only minimal extraction and transport costs, surplus agricultural production from the United States began to appear to the world at large as an answer to momentary or even more long-term shortages in local food production.

Through both aid and trade channels, the United States sought actively to export its agricultural surpluses. Since most capital cities of Third World countries were constructed as ports or transshipment centers during the colonial period, it became very easy and even appeared wise to purchase cheap American grain surpluses to feed growing urban populations in the Third World. When disasters like floods, earthquakes, or typhoons hurt the remaining local agricultural systems, U.S. aid agencies provided relief supplies of food at cost through PL 480 funds and the Food for Peace program. In the face of the massive arrival of food surpluses from the industrial world, it became clear that peasant farmers -- often situated in remote rural areas with poor transportation links to the cities -- were not generally able to engage in profitable competition with Western farmers and the state apparatus of industrial nations that together had the power to dominate agricultural "markets" in the Third World.

The cyclical and self-perpetuating nature of the problem started to become apparent by the early 1960s. Peasants, trying to stay afloat economically, began to devote more and more of their arable land to cash cropping, which, in turn, provided less and less income in relative terms the more crops they produced. In the process, with relatively less land and labor devoted to foodstuff agriculture in Africa, not only its urban areas, but also major rural regions became dependent from the 1960s onward on substantial imports of foreign surpluses. According to one observer, "food imports rose from 4 million to 24 million tons during the 1970s. By 1985 the continent was importing two-fifths of its food supply, and about a third of its people depended wholly or partly on imported food."[18] Meanwhile, those peasants or their children who had left the village began to swell the ranks of the urban areas with no real prospects for steady wages.[19]

Politically this was a volatile situation because hungry urban populations could prove to be explosive. Quite understandably, then, urban-based political elites tended to continue to buy political tranquility in the short run by purchasing food from the cheapest source -- the surpluses of Western industrial countries. In order to purchase this foreign food, the state exhorted its cash-cropping peasants to produce ever greater quantities of export commodities so that it could obtain the foreign exchange for the increasingly necessary food purchase transactions. While cash-crop exports expanded, commodity prices dipped with oversupply, and foreign exchange became scarce, despite expanded output. In this circumstance the states concerned either had to seek food aid or incur foreign debt to purchase the food upon which they had come to depend. Indebtedness proved to be only a short-term solution, for with the increase and unsteady fluctuation of interest rates, many African countries soon found themselves having to devote much of their foreign exchange earnings to servicing these debts. The overall debt burden for the continent rose from $14 billion in 1973 to an estimated $125 billion in 1987.[20]

The rapid rates of urbanization that contributed to the pattern of collapse in local agriculture had yet another demographic impact on the rural areas. Faced with the departure of the young, able-bodied members of their households, families often resorted to having several children in the hope that some would remain to undertake the ever-more-demanding cash-crop work. Collectively this translated into a rapid spurt in population growth, particularly as this period also witnessed the arrival of rudimentary medical facilities and the equipment for clean water supplies in rural areas. Both of these latter phenomena contributed to the decline in infant mortality, and the result over time was a rapid rise in absolute numbers in rural areas.

During the 1950s and 1960s those portions of these growing populations that remained on the land greatly expanded the areas devoted to agricultural activity without substantially changing the technologies applied to production. The result was enormously taxing upon the land itself and the environment in general. In bush-fallow systems of land usage, fallow periods were shortened or eliminated altogether, and on the thin and nutrient-poor soils this new pattern of usage rapidly exhausted arable lands. In addition, previously undisturbed forests began to be cleared under a twofold pressure. First, the relative decline of commodity prices for coffee and cocoa left the state short of foreign exchange, and it began to extend rights to timber concessions for cutting and exporting tropical hardwoods as a means of shoring up sagging trade balances. Secondly, peasants hoping for new cash-cropping opportunities or those in search of fertile land for growing food began to encroach upon remaining zones of uncut forest.

Removal of large portions of tropical forest cover and conversion of whole regions to cropland and grassland had the effect of changing the nature of the local hydrological regime. Water previously held in the canopy or locked in the root systems of vegetation in the forest would subsequently run off at accelerated rates with little or no ground cover left to hold it. Dramatic flooding became a feature of the rainy season in many parts of Africa, and considerable amounts of topsoil were lost to sheet and rill erosion. This further depleted the agricultural potential of the land. The deterioration became particularly acute in areas subject to annual foodstuff production. By comparison, the land devoted to plantation cash-crop agriculture largely retained and in some cases enhanced its fertility. Over time the disparities between the amounts of land devoted to export production and those remaining for food production became all the more pronounced. Some rural regions of Africa have been so overgrazed, overcropped, and eroded that it is doubtful that agriculture can continue on these soils for much longer without considerable imported subsidies to rebuild soil structure and fertility.

Soil fertility is not all that is involved in this cycle of decline. The rainy-season floods are frequently followed in local areas by dry-season droughts. The water in the annual hydrological cycle is not maintained in watersheds to be drawn upon over the full year.

Instead it rushes though the region, often taking all before it in the rainy season, only to leave sun-baked clays and dried-up wells in the ensuing months. In areas where soil depletion and loss of ground cover has proceeded for decades, it is even possible that local weather patterns can shift over time.

While the global climate fluctuates over periods and with dynamics that are not yet fully understood, it nonetheless seems that regional weather patterns or microclimates can be significantly altered in a matter of generations or even decades if major shifts in land and water use are engendered by new patterns of resource exploitation. Mankind can foster the processes of desertification by pursuing unwise development strategies or by encouraging peasants to overtax their land and water resources. While there seems to be a pattern of periodic drought in Africa, there may well be an anthropogenic component to the climatic anomalies that the continent has witnessed over the last two decades.[21]

In cases of local or regional drought, populations that have become dependent upon purchasing food in exchange for cash can find themselves short of food for reasons well beyond their control. Fluctuations in the price of oil affect both international shipping and internal transport costs of food as well as the total foreign exchange profile of individual countries. Thus, the fitful increases in oil prices have been translated in local terms in Africa into an increase in the price of imported food and occasionally a pattern of seasonal or chronic shortage. This is compounded as the world market in grains fluctuates with the purchasing habits of major industrial countries. When Soviet, Chinese, or Indian harvests are poor and Western grain surpluses are bought up on the international market, African countries find themselves facing prices beyond their purchasing power. As we have seen in recent years, food shortages can become acute and famine widespread in these circumstances.[22]

Crash efforts to develop "modernized" agriculture based on "green revolution" technology are offered by Western agricultural experts in the wake of these famines to meet the urgent and evident need for expanded food production, but in ecological terms these kinds of development projects should be examined carefully before they are adopted. Generally these technological packages are based upon "high-yield varieties" (HYVs) of crops that have been selected to respond to a combination of fertilizers and pesticides designed for their needs. In this regard the HYVs are more appropriately labeled "high-response varieties" (HRVs). They respond well to the petrochemical subsidies they were engineered to use, but on their own their performance may well not even equal that of traditional varieties.[23] When one considers the probable rise in cost of the petrochemical additives needed to make them produce, together with the infrastructural investments required for irrigation systems, storage systems, and mechanized equipment associated with the "modernized" agriculture, it is not clear that the choice of these technologies is a wise one for the Third World in the long run.

On the contrary, similar investments in roads, marketing facilities, or land directed towards traditional crops may well prove over the long run to be better spent than the money devoted to the alluring promise of "miracle" crops. The real costs of HRVs become apparent only over a period of several years or decades as it becomes clear that adopting this kind of agriculture amounts to transforming biosustainable, solar-based agricultures to petro-subsidized systems of production.[24] In the face of declining petroleum supplies it is questionable whether development schemes based upon increasingly energy-intensive technologies can be sustained much longer.

Another element of the underdevelopment spiral leading to chronic environmental degradation in Third World rural areas is the problem of undernutrition, malnutrition, and the resultant spread of chronic and epidemic disease among the population. Undernourished and malnourished populations generally experience higher infant mortality rates than well-fed populations. Increased infant mortality can lead to the impulse to have more, not fewer, children if it engenders a generalized anxiety on the part of peasant parents to be able to supply their labor

needs and means of support in their elderly years. In general, fertility rates decline *only after* mortality rates have begun to decline for a noticeable period among peasant populations. As long as disease patterns or economic hardships assure that mortality remains high or actually increases, fertility itself is likely to remain high as well. There now seems to be no assurance that the Third World as a whole will be likely to experience the same kind of "demographic transition" that characterized the population history of Europe during the last several centuries of its economic development precisely because deteriorating conditions in the Third World may keep mortality levels high. Chronic famine in Africa has made this dramatically apparent.

Beyond the question of mortality and its indirect effects upon fertility, there is the problem of endemic morbidity -- the debilitating phenomenon of chronic or epidemic disease. In agricultural societies dependent upon manual labor, chronic levels of disease seriously reduce productivity over time. This is particularly true at serious labor demand periods when food is in short supply. Poorly fed populations can be either too sick or too weak to undertake the extra work needed to adopt conserving measures in their cultivation practices or even to assure proper preparation of their fields for planting. Nearly all the peasants I have worked with would like to be able to plant on larger surfaces than they do, but they are either not able to mobilize the labor or not capable of undertaking the extra work themselves. A peasant who repeatedly becomes sick or incapable of planting his own food is in a dangerously precarious position.

As the colonial regimes recognized, investments that improved public health were well worth their expense because of the benefits to rural production they would engender. Conversely, the post-colonial governments that are short on investment funds and do not provide adequately for public health in rural areas are likely to witness a measurable decline in agricultural productivity over time. In regions of East Africa now struck by AIDS, agricultural production has been reduced appreciably. More pervasively, a drug-resistant form of malaria is beginning to gain hold in parts of Kenya, weakening populations and reducing work capacity.

As circumstances in rural areas become more desperate, some peasants may leave their regions in search of better conditions elsewhere. When this is done individually it often takes the form of rural-urban migration. In areas where urban employment is not encouraging, however, this can take the form of rural-rural migration of laborers, either as seasonal or permanent workers in new lands. When large changes occur in the development potential of whole regions due to drought or irreversible ecological deterioration, sometimes whole communities have moved. At the height of the drought in Chad, 500,000 people were said to be on the move with all their possessions and livestock from northern regions to southern regions of the country.

These massive migrations of population were at one and the same time a symptom and a cause of environmental degradation. The movement of cattle stock into more restricted ranges threatens the accommodating territory with overgrazing and places pressures on the available water supply. Once populations in this migrant state become dependent upon relief supplies of food aid in order to eat, the major problem becomes how to design agricultural systems that can help them reestablish their agricultural autonomy, usually on a severely impoverished resource base. Often this cannot be done, and today there are more than five million people on the African continent who live in refugee or relief camps of some sort.

Whether in refugee camps or in the expanding shantytowns surrounding major urban agglomerations, the growing populations, uprooted from productive agricultural activity, strain the ability of the state to deliver even the most elementary of services. Demand for housing, clean water, electricity, and food outpaces the supply provided through state or authorized private sector channels. The result is often the emergence of an underground economy or black

Herman Daly, author of *Steady-State Economics* and long-time critic of conventional economic growth theory, is currently working at the World Bank. Analysts of bank policy regard Daly's appointment as a remarkable reversal, but it remains to be seen to what extent Daly's perspective can prevail in a bureaucracy as accustomed to growth-oriented criteria of success as the bank has proved to be in the past. See: Constance Holden, 1988, A heretic amid economic orthodoxy, *Science* 240:1611.

14. This question is asked directly in an extended article by Edwin Goldsmith, 1985, Is development the solution or the problem?, *The Ecologist* 15(5/6):210-219.

15. In taking into account the environmental costs of various development strategies, scholars have tended to neglect the ecological impact of open conflict that is predictably unleashed when particular development policies are pursued. This is a curious omission and marks a peculiar kind of blind spot in assessing development strategies. Not all concerns are similarly myopic. Businesses involved in Third World agriculture projects regularly include considerations of "security" as part of the operating costs they need to incur to protect their investments. If peasant resistance or sabotage to these projects becomes too expensive, the enterprise nearly always calls upon the state military apparatus to undertake the effort and expense of suppressing peasant opposition. The costs of repressing peasant revolts are readily calculable in terms of munitions and manpower, but the costs to the peasants' environment or the world's ecosystem of doing so are usually overlooked as an "externality" in the whole process. If we are to develop a reasonable means of assessing the environmental costs of development strategies, we should try to include this "externality" in our calculations.

    The policy implications of undertaking these economic calculations would be significant because whatever the economic virtues of pursuing capitalist development strategies in regions like Central America, the ecological destruction involved in crushing peasant rebellions or launching "contra" insurgencies is massive and needs to be counted as a real cost in any cost-benefit analysis of any proposed development strategy.

16. The potential ecological impact of nuclear war has attracted much attention recently, but all kinds of war are clearly costly to the environment. An examination of the ecological effects of "limited" wars, particularly those against peasantries in the Third World, can begin with the Stockholm International Peace Research Institute's 1980 study, *Warfare in a Fragile World: Military Impact on the Human Environment*, London: Taylor and Francis; and Arthur H. Westing, ed., *Herbicides in War: The Long-Term Ecological and Human Consequences*, London: Taylor and Francis. These internationally commissioned reports have largely been ignored in the United States, perhaps, once again, because current American political leadership finds it difficult to accept responsibility for the chemical warfare techniques used in recent wars in Indochina and advocated by some for current use in Central America. Indeed, given its opposition to compensation for alleged "agent orange" disabilities among its own veterans, current administration reluctance to examine these issues publicly is perhaps understandable if not excusable.

17. Much of the debate between social scientists analyzing environmental crises in the Third World is over the question of where to ground the fundamental starting point for analysis. From the perspective of systems thinking adopted here, this kind of debate is as pointless as it is fruitless. Such debates often deteriorate into "which is the better: social science? economics? demography? sociology?, etc." The point is that no particular perspective deserves priority, but all must focus on the connectedness, the fundamental interrelatedness, of these phenomena if an effective means of addressing our environmental crises is to be developed.

18. Jennifer S. Whitaker. 1988. *How Can Africa Survive?* New York: Harper & Row. 18.

19. Urbanization is occurring at rates that exceed population growth in most of Africa, and at current rates experts estimate that fully 45% of Africa's population will live in urban or semiurban areas of 4,000 or more by the year 2010. The massive expansion of urban areas is not uniquely an African phenomena. Mexico City is already the largest city in the world and growing at a rate of one million per year. Asia will have 23 cities with populations of five million or more by the year 2000. See: Population boom for Asian Pacific, UPI news wire, 7 June 1988, 17:47 p.m.

20. Jennifer S. Whitaker. *How Can Africa Survive?* 19.

21. On the interaction of human activity and climate, see particularly: Richard W. Franke and Barbara H. Chasin, 1980, *Seeds of Famine: Ecological Destruction and the Development Dilemma in the West African Sahel*, Montclair, NJ: Allanheld, Osmun; Alan Grainger, 1985, *Desertification: How People Make Deserts, How People Can Stop and Why They Don't*, Washington, DC: International Institute for Environment and Development; and Independent Commission on International Humanitarian Issues, 1985, *Famine: A Man-Made Disaster?* London: Pan Books.

22. Ecologists hesitate to make predictions, but circumstances in mid-1988 do not present a promising picture for countries that have become irreversibly dependent upon North American agricultural surpluses. The United States drought of 1988 has hit oat and corn harvests severely. In addition, China is experiencing a simultaneous drought, causing some observers to suggest that food surpluses may dwindle in the coming year. While the Soviet Union is predicted to have a bumper crop in 1988 and some South American countries are going to take up the slack in production experienced in the northern hemisphere, agricultural analysts are wary about the prospects for long-term food security on a global scale. See: Food experts study hunger in the midst of plenty, UPI news wire, 4 June 1988, 16:56 p.m.; Drought may sink grain stocks, Associated Press (AP) news wire, 26 June 1988, 15:32 p.m.; Food threats, USDA expert sees trouble ahead, AP news wire, 10 July 1988, 4:12 a.m.; Soviet harvest, bumper crop seen for Soviets, AP news wire, 12 July 1988, 19:17 p.m.; and Drought is boon to S. America, AP news wire, 22 July 1988, 13:13 p.m.

23. For assessments of the shortcomings of the green revolution, see: Kenneth A. Dahlberg, 1979, *Beyond the Green Revolution: The Ecology & Politics of Global Agricultural Development*, New York: Plenum Publishing; Tim Bayliss-Smith and Sudhir Wanmali, eds., 1986, *Understanding Green Revolutions: Agrarian Change & Development Planning in South Asia*, New York: Cambridge University Press; Edward C. Wolf, 1986, *Beyond the Green Revolution: New Approaches for Third World Agriculture*, Worldwatch Paper No. 73, Washington, DC: Worldwatch Institute; and Bernhard Glaeser, 1987, *The Green Revolution Revisited*, Winchester, MA: Allen & Unwin.

24. For critiques of the energy costs of petroleum-subsidized agriculture, see: Maurice B. Green, 1978, *Eating Oil: Energy Use in Food Production*, Boulder, CO: Westview Press; and John Gever et al., 1986, *Beyond Oil: The Threat to Food and Fuel in the Coming Decades*, Cambridge: Ballinger. Concerning the deadly impact of pesticides necessary in petro-subsidized agriculture, see: David Weir and Mark Schapiro, 1981, *Circle of Poison: Pesticides & People in a Hungry World*, San Francisco: Institute for Food & Development Policy; David Bull, 1982, *A Growing Problem: Pesticides and the Third World Poor*, Oxford: OXFAM; and David Weir, 1986, *The Bhopal Syndrome: Pesticide Manufacturing and the Third World*, Penang, Malaysia: International Organization of Consumers Unions.

25. Widescale corruption in public office is often offered as an explanation for Africa's sad state of affairs, particularly by journalists. See, for example: Xan Smiley, 1982, Misunderstanding Africa, *Atlantic Monthly* 250:70-80; and J.S. Whitaker, 1980, *How Can Africa Survive?*, New York: Harper and Row, 48-52. The sanctimonious tone of the moralism in some of the recent writing from the United States seems somewhat misplaced in light of revelations concerning the level of corruption and official misconduct currently tolerated at the very highest levels in this country. More to the point, corruption is far better understood as a symptom of systemic malfunction rather than as its basic cause. Nevertheless, the amassing of private fortunes in public office and their expatriation into foreign bank accounts constitutes a massive "capital flight" from many developing countries and thus exacerbates the underdevelopment spiral.

26. This has also led in the case of failures to recriminations leveled across disciplines, essentially accusing planners of listening to the wrong experts. See, for example: Polly Hill, 1986, *Development Economics on Trial: The Anthropological Case for a Prosecution*, Cambridge: Cambridge University Press. As satisfying and necessary as these salvos may prove to be in the first stage of critiquing development failures, something more is necessary at this stage. The fundamental understanding of what constitutes an expert needs to be reassessed.

27. Planners may be ill-served by universities -- the traditional source of "experts" -- in this regard. Employment in the university context is frequently only possible within the structure of departments, and these departments have tended to retain and promote only those who are thought to make contributions to disciplinary subspecialties. Disciplines and subdisciplines are of necessity becoming more and more specialized with heightened skills and refined research methodologies. It is the further contribution to specialized knowledge and not the clarity and scope of integrative thought and planning that is generally rewarded in universities as they are currently structured. Universities may well have to rethink their structures of inquiry and reward if they wish to have anything useful to say amidst the global ecological crisis.

28. There are several helpful beginnings in rethinking development within sound ecological principles. See: John M. Culbertson, 1971, *Economic Development: An Ecological Approach*, New York: Alfred A. Knopf; Raymond F. Dasmann, 1973, *Ecological Principles for Economic Development*, New York: John Wiley & Sons; Dennis Meadows, ed., 1978, *Alternatives to Growth: Vol. 1, A Search for Sustainable Futures*, Cambridge, MA: Ballinger Publishing; W.C. Clark and R.E. Munn, eds., 1983, *Sustainable Development of the Biosphere*, New York: Cambridge University Press; Michael Redclift, 1984, *Development and the Environmental Crisis: Red or Green Alternatives?*, London: Methuen; Brian Spooner, 1984, *Ecology in Development: A Rationale for Three-Dimensional Policy*, Paris: The United Nations University; Peter Bartelmus, 1986, *Environment and Development*, Boston: Allen & Unwin; and Bernhard Glaeser, ed., 1986, *Ecodevelopment: Concepts, Projects, Strategies*, Oxford: Pergamon Press.

29. See particularly: Michael Redclift, 1987, *Sustainable Development: Exploring the Contradictions*, London: Methuen.

30. George Wald, personal communication and his 1986 article, The Third World debt: a key to world problems, in *Democracy in International Relations*, Vienna: International Progress Organization, 43-48.

31. Barbara J. Bramble. 1987. Debts for nature: the debt crisis: the opportunities. *The Ecologist* 17(4/5):192-199.

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Environmental Opportunities and Limits for Development

Reid A. Bryson

I was supposed to talk about environmental *limitations* on development, but I want to emphasize at the outset that there are also environmental *opportunities* for development and that the "limits" we speak of are often physical limits -- hard, fast, absolute limits. I also want to emphasize the time factor involved -- that is, development now or development later.

Dust, Goats, and Deserts

To illustrate the environmental opportunity for development, I will start with the story of an interesting scientific adventure. When I first flew over northern India in the spring of 1962, I could not see the ground and, from 17,000 feet in an old propeller-type airplane, I could not see anything other than the tips of the Himalayas sticking up above a dense haze. But as we began to descend over the desert state of Rajasthan I could vaguely see villages through the dust in the air. There was nothing strange about the villages except that all around them there were light-colored areas. Those light-colored areas had been totally stripped of vegetation. Even in satellite pictures of this region of northern Rajasthan one sees, about every mile, a little black spot -- a village -- surrounded by a white halo where the vegetation is totally gone. It is that stripping of the surface that exposes the soil to the wind and provides the dust in the air.

Most people, when they get to Agra, which is near the edge of the desert in a semi-arid area, see the Taj Mahal and say, "Isn't it a beautiful gleaming white?" But step back a little bit and it isn't so gleaming white because there is something in the air in between. As the spring progresses, that "something in the air" grows thicker and thicker. At ten o'clock in the morning on a cloudless day the sky is so obscured by dust that the sun may be photographed without fear of burning the camera shutter. Dust, dust, and more dust. I thought, in 1962, when I first saw that dust, that there was so much of it in the air that it had to affect the sunlight intensity at the ground. If you have ever had a course in physical geography, you know that it is the sunlight that controls the climate. Enough dust will modify the climate.

I returned once or twice a year over the next 10 years to explore this question of the possible impact of dust on the climate. We measured. We measured the outgoing radiation at various heights in the atmosphere with instrumented balloons. We measured the incoming and outgoing radiation and the dust from an instrumented aircraft. In order to fly high enough to get to the top of the dust, we had to bring in our own aircraft. We eventually discovered that there was enough dust there to change, distinctly and significantly, the radiation from the earth and the sun and that these changes made the air sink. Now when air sinks it suppresses rainfall. If you suppress the rainfall, the vegetation is more susceptible to stripping, the soil surface is more easily exposed, and more dust is blown into the air. With more dust in the air, the climate is modified so that the air sinks. When the air sinks, it makes the region drier. When it is drier, there is more dust, when there is more dust, there is less rain, less rain, more dust, more dust, less rain and on and on it goes.

It occurred to me that perhaps we could change the climate of this region. This desert -- the state of Rajasthan is largely desert -- has a population of 34 to 40 million. It is the most densely occupied desert in the world. Would it be possible to improve the lot of the people living there by controlling the dust and so modifying the climate? We went into the region to find out, first, how long it had been dusty. We have historical records dating from the fifthcentury A.D. in which travelers comment on the dustiness of the region, but I wanted to know when and why and how it started to get dusty.

Using methods developed here at Wisconsin, we reconstructed the climatic history of the region from the record that nature had left behind as plant pollen. As one travels into the middle of Rajasthan, one finds the many little villages that lack surrounding vegetation. It has all been pulled up, mainly to start fires of animal dung or to feed animals. The area, though, is densely occupied. Out in the middle of the sand dunes one finds people walking along. In fact, I was rather startled to see that there were more footprints than ripples on the sand dunes. It is a *very* densely occupied area. And wherever one looks, the surface is nearly bare. All that can grow on the surface is that which goats cannot eat.

Then one day we came upon a very interesting phenomenon: a fenced area surrounded by a row of trees[1]. Inside the fence line we found grass -- tall, lush grass. Beyond the fence was desert. What was done there to grow grass? Absolutely nothing. The area was part of a government-funded agricultural experiment station. The researchers had fenced off an area where they were going to do an experiment, but then their budget ran out. So they waited for the next year. What did they do inside the fence? Nothing. They left it, and after one year there was tall, beautiful grass instead of bare desert. When I saw that I thought, "Aha! The natural vegetation of this region is not desert; it is tall, lush grass." Why was there grass there and nowhere else nearby? Because within this enclosure there had been no goats and outside there had been. The large numbers of goats kept the whole region free of vegetation. Now, the trouble with goats is that, nice little critters though they are, they will eat all the grass and then pull up the roots and eat them. When the roots are all gone, when do you get the next grass for goats to eat? Next summer. The following summer, seeds -- if there are any -- will sprout because rain falls in the summer monsoon period, and only then. If the goats pull up the roots, there is no more grass until some seeds germinate the next summer.

Observing this situation, I thought of Wisconsin, where some farmers do a related thing with cows. Instead of letting their cows out to muck up the pasture and ruin it, farmers here will often keep the cows in a pen, cut the hay from the pasture, and take it to the cows. In a desert climate, the vegetation is even more sensitive, so I said to the scientists at this experiment station, "Suppose that you pen-fed the goats here. The fact is that bare surface conditions create dust and suppress rain, and the surface is made bare by all those goats as well as the desert conditions. Your inadvertent experiment shows you that if you put the goats in pens, cut the grass, and take it to the goats, the grass will continue to grow and you can cut some more. And it will continue to grow, and you can cut still more and you won't have to wait until the next monsoon season. Why don't you lay out some demonstration plots for the people to see. Put up a fence and put a sign by it and tell the people who cannot read, 'Look what happens. All this beautiful grass will grow if you do not let the goats graze, and you can cut it and take it to the goats. Maybe you can raise twice as many goats.'"

I went back the next year and they had put up some of these demonstration plots. An interesting thing had happened. The fence had been cut and goats had been allowed in so it was largely eaten out. After all, there was all that beautiful grass there, and nothing on the outside. That was about 1965.

In 1985, my wife and I were back in the same area with a television crew. Maybe you saw the film as part of the *Planet Earth* series. We were riding out into the same desert, from the Central Arid Zone Research Institute in Jodhpur. I got to talking to the taxi driver and he asked, "Why are we going out here?" I said, "To make a television documentary in an area I did some research on 20 years ago." He asked, "What was the research?" We were just passing some goats at the time, so I told him about the goats. And the driver's eyes grew as big as saucers as he said, "Oh, are you where that idea came from? We did it in our district of Shergarh. We did it and it doubled the number of goats that we could feed. We even hired chokidars [guards] to see that people did it your way." It made me feel wonderful. But later on, talking to a biological scientist from one of the universities in the area, I was told that the taxi driver

was wrong. Pen-feeding did not just double the number of goats -- it increased them by a factor of five.

Did I do a good thing or not? I think that it could be called development. Right? Here was a development that increased the short-term well-being of the people. They could have more goats, which supply milk and meat. In fact, the area does not even look the same anymore. It is much greener and much more vegetated than it was when the goats were open-pastured. I think that was development. But I still worry about it. The reason I worry about it is that with five times as many goats and with better planning of their agriculture (again a Wisconsin development; we showed them how to anticipate the rainfall of the coming monsoon seasons so they could plan their cropping more efficiently), inevitably there will be more people. And I cannot help but remember what an elderly woman said when we were trying to interview her on this last trip. We were talking about climatic variation and the producer asked the elderly lady, "Madam, what happens when the rains do not come?" She said, simply, "We die." When he asked her to elaborate on that, she said that there was nothing more to say. "If the rains do not come, we die." She shooed us away and would not talk about it any more.

The problem is that the development was for *now*. The environmental question is whether that development will lead to a larger population so that when the rains do not come -- and inevitably they will not -- there is more pressure on the land, there are more people there, and the people die. It has happened before. This is where our pollen analysis and climatic history enter the picture. Figure 1 is the record of the rainfall in that area that we reconstructed from the record that nature left behind. It shows how much rainfall there was, century-by-century, over the past 10,000 years and how that rainfall varied. At the beginning of this period there was a lot of rain compared to the present. But about 3,600 or 3,700 years ago, the rains ceased, the lakes in the area dried up entirely, the sand dunes formed, and the area lost its human population. It had been the home of a vast agricultural civilization. But for 700 years the monsoon rains failed. And when the rains came back, an entirely different people resettled the region. Instead of the Indus, Aryan nomads occupied the area.

Let us go back to figure 1 because there is another thing I would like to point out. Nearer to the present, by about 1200 years AD, the rains had come back somewhat, and then there was a wetter period followed by dry conditions up to the present time. These were field data. A model, figure 2, shows the same thing. It shows the decade-by-decade rainfall from about a 1000 AD up to the present. Notice that about 1200 AD the plateau of rainfall drops off. The little "f"s down at the bottom indicate historically recorded famines. Did the people die? Well, they died -- but they also left. Out in the middle of the area where we worked, there is the town of Osian. I was told that this was a new town. When I got there I looked at it and said that it did not look very new to me. "Oh, yes, yes, it's a new town." "Well, why is it a new town?" "It is a new town because every time they dig a hole they find the remains of the old town. The old town dated back 3,700 to 3,800 years ago. The new town was only started 2,900 years ago. It's very new." It had reached a peak of development in what was probably the first republic in Asia. It was the Republic of Osian or the Oswali Republic. It reached a peak in the wet period that we saw. The history of the Oswali says they left because it became too dry. They are distributed all over India now. They left because they *could* leave.

Now, with 750 million people in India, could the population of this region, if it turned dry again, just pick up and leave? With no place to go? The world does not have open country. It does not have new worlds to conquer. This timing of the abandonment of the Oswali Republic matches the field data, and their own history says, "We left because of the drought; the rains failed." People have come back now, and there are tube wells and electric pumps. There is pen-feeding of goats. The population is booming. But some day the rains will fail.

So, the time factor in development is important, but so is the nature of the development -- what development *does*.

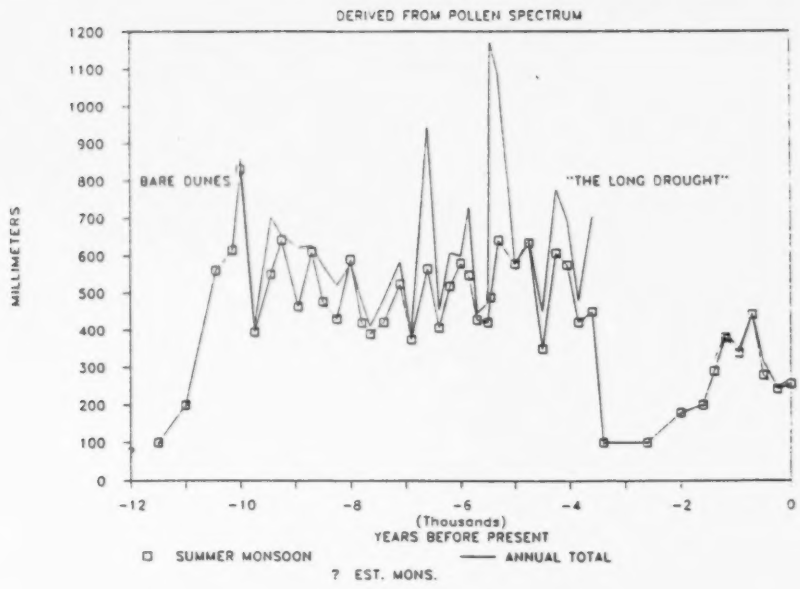

Figure 1. Past monsoons at Lunkaransar, Rajasthan, India

The history of monsoon rainfall reconstructed from fossil pollen recovered from a core of sediments in Lunkaransar Dry Lake in Rajasthan, India. Particularly noteworthy is the long drought, associated with the disappearance of the Indus (Harappa) culture, that started about 3600 BP. "Est. Mons." means estimated monsoon rainfall, based on other evidence.

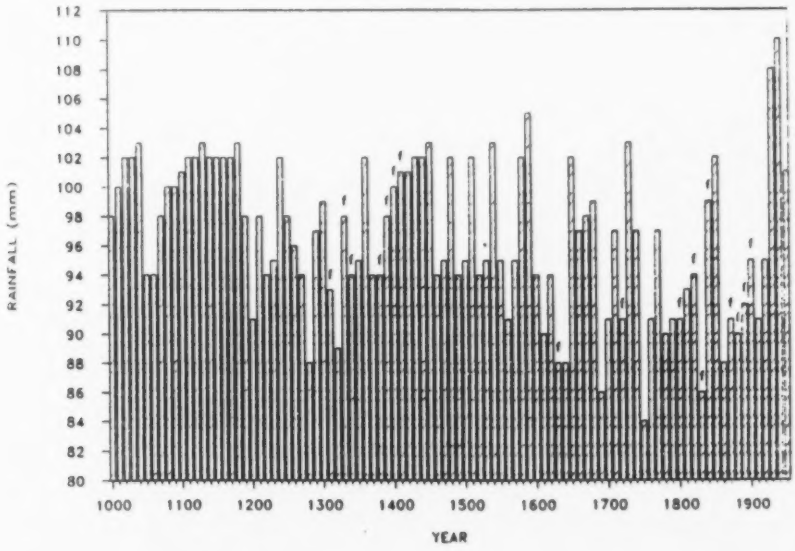

Figure 2. Estimated decadal rainfall -- northwest India

Reconstructed rainfall in northwestern India, decade by decade, for the past millennium. The small "f"s indicate historically recorded famines. After Brinkmann.

Carrying Capacity

I want to show you with a graph what development can do. It is an example from the animal world, but animals eat just as people eat. Sometimes people eat animals, and sometimes they eat grain, but the principles work on either one. Figure 3 shows the historical levels of the cattle population on the veldt in Kenya compared to the amount of rainfall. It shows that when the rainfall goes up, the number of cattle goes up. And when the rainfall goes down, the number of cattle goes down because the number depends upon how much grass grows, and how much grass grows depends upon how much rain falls. It is as simple as that in this area.

Then along in the middle of the 1950s "development" stepped in. The cattle were inoculated. Efforts were undertaken to make them breed better and survive disease better, and so, with slightly above average rainfall, the cattle population grew to its highest level in history. Development produced more cattle. But look what happened. There were more cattle, but when the rain decreased in 1959, the population of cattle dropped dramatically. This was due in part to the fact that there were so many cattle on the veldt that, as soon as the rain diminished, the loading of the pasture was too high, and the cattle quickly destroyed what grass there was left. The range deteriorated and there was a crash in the number of cattle that it could feed.

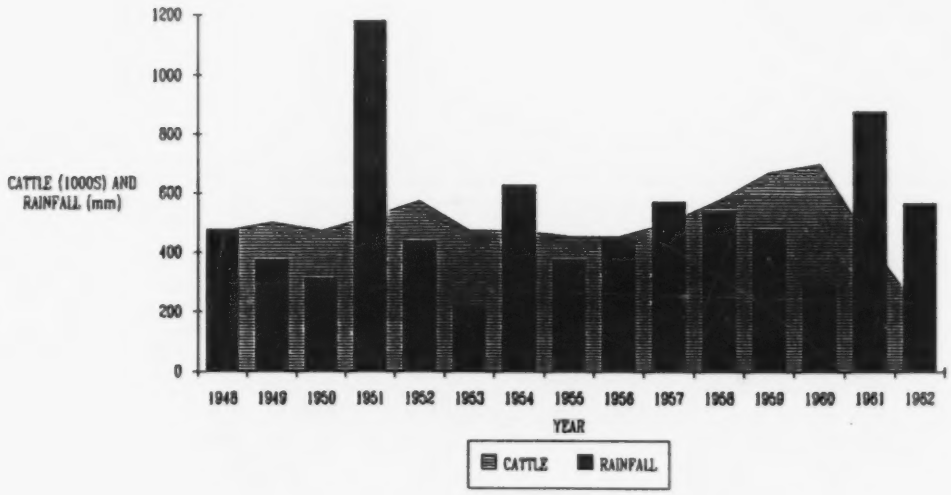

Figure 3. Rainfall and cattle population -- Kenya

Cattle population of Kenya compared with rainfall. The numbers of cattle (line) increased when the rains (bars) were good and decreased when the rains diminished, but the very large numbers after "development" experienced a larger crash.

The same principle applies when we increase the population of people. Figure 4 provides an example. It shows the course of rainfall in sub-Saharan Africa. The rainfall went up in the early part of the record. In the 1950s many wells were drilled to provide more water for the cattle that fed the people, who also farmed a little bit.[2] The amount of rainfall decreased after that time, so about 1972 people started to die. There was a great ruckus in the media about the Sahelian drought, and we moved to get relief to them.

We see, then, the same pattern as in the previous example. During the wetter period the numbers of cattle and people increased very rapidly. Some of the highest birthrates in history were recorded in this region at that time -- an enormous rate of 4.7% per year. But it was the same story as in Kenya: When the rains dropped and the carrying capacity of the ranges went down, then the food supply dropped, the cattle died, the people died or moved to the cities,and large relief efforts began. But popular interest in relief operations is short-lived. In 1972 there was a big crisis. In 1974, in the northern part of the sub-Saharan region, there was a slight increase of rainfall, though not even to normal levels, and many "experts" said, "The drought is broken. We can forget about it now." It was not broken. And you will remember that just a couple of years ago, it once again became popular to send relief to Africa where people were dying because of the drought. They had been dying all along. Development did not save them from it. In this kind of land the old lady was right. What happens when the rains fail? We die.

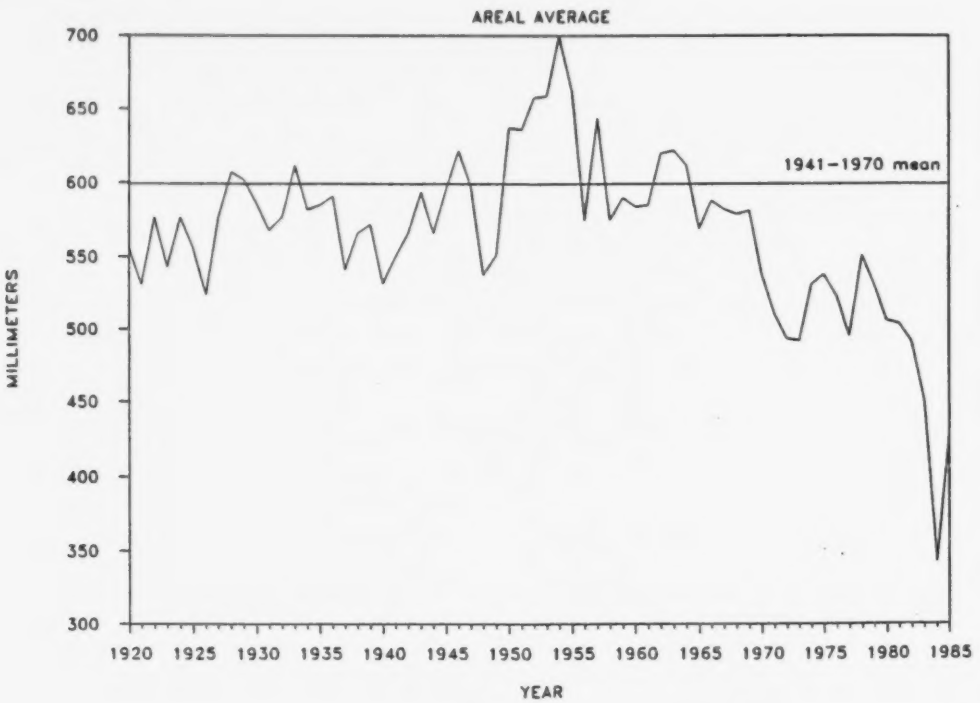

Figure 4. Annual rainfall for sub-Saharan Africa

Annual rainfall averaged over sub-Saharan Africa. It is clear that the "Sahelian drought" did not end in 1974.

Of course, there are various ways to show that these assumptions about the end of the drought were not necessarily true. Getting that message across, however, was a different matter. One of the things I heard back in the 1970s when I started commenting on this was, "You should not be working on this problem because this is Francophone Africa and you are not French." (Can the Africans only be saved by French-speaking people?) Or, "Those have been British colonies; it's our business and not yours. We have a special responsibility." Well, fellows, why did you not do something about your special responsibility? Because research, with the facts, not with theories about what language one spoke or whose colony it was, made possible some conclusions even back then.

In 1973 I said the following about the rains in sub-Saharan Africa: "Will mankind give up burning fossil fuels so that the monsoon rains will return? No way. Will the volcanos please settle down, because volcanos affect the radiation through the atmosphere that drives the rains? Probably not, since the volcanoes are already less active than normal, looking at it from a longer viewpoint. Will mankind go easy on particulate air pollution? No. [As people in a developing country once said to me, "It is now our turn to pollute."] Will the monsoon return to West Africa? Probably not reliably in this century." This was published in 1973. But 1974 saw a slight increase in rain: "Ah, the drought is broken." Do you ever hear of the *rains* being broken? No. But droughts get broken. It's all in the way you look at it.

Environmental Limits

We have been considering delicate balances between one factor and another. Now let us consider some absolute limits. We know that the sun drives the climate and the weather. It drives the weather machine by providing the fuel. In fact, the sun provides the fuel that drives us, too. Whether it be fossil sunlight in the form of fossil fuels or fossil sunlight from the big burst of light at the beginning of the solar system -- nuclear energy -- or whether it be the sunlight stored in the food that you buy at the store or grow in your garden, it is the sun that fuels the world and us.

Suppose we take all the sunlight that falls on land that is being or can possibly be used for agriculture, and suppose we grow efficient crops that will store up about 4% or 5% of the sunlight in biomass, of which maybe 5% may be edible (we do not usually eat the roots of the wheat or corn). Most people in the world live on grain. But, of course, we are not able to process the energy in our food with perfect efficiency either. (After all, manure is good fuel. Ask anybody in India, where 66% of the fuel reserves are dried manure. There is a lot of the energy that goes on through.)

Now consider all this in units of watts. A person generates 150 to 300 watts of heat. There are perhaps 200 of you here, for example, each producing about 200 watts. That is like four kitchen ranges going full blast. Well, we know how much it takes to feed a person, so how much land does it take to yield the appropriate number of watts in food energy? If all of the sunlight is efficiently converted, it takes something like 899 square meters of land. That is bigger than the average back yard by quite a bit. On the average, sunlight is available to grow things only part of the year. Thus if we used all of the farmland in the world at the maximum allowed by the amount of sunlight falling on it, the *sunlight limit*, how many people could a hectare (2.4 acres) support? It could support 5.56 persons. (See appendix A for the calculation of the sunlight limit.) How many per hectare are there now? Three. We have not yet reached the absolute limit. How long will it take for the world population to double from the five billion we have now to 10 billion? Forty-one years at the present rate.

Before it doubles, in less than 41 years, we will have gone from three persons per arable hectare to the sunlight limit. At the present rate that should take about 35 years -- within your lifetime.

I am not against development. I proved that. I have done it. But I want you, because you are going to last 35 years and I will not, to think about the fact that there may be that absolute limit out there.

To grow food one must have water. Deserts are not very good at producing food. We can go through the same kind of analysis for water. Suppose we pack all the people on the land as tightly as the sunlight will allow and then figure out how much water is required to grow the food to support them. It takes between 1,000 and 2,000 cubic meters of water per person per year on that cropland to do it.

Consider the total amount of water that falls on a country like India and how much must run off because of the heavy rains in the summertime. There is no way one can stop the runoff from the monsoon entirely, especially if much of the population lives on the flood plain, so only about 20% of the rainfall is available for use. Twenty percent of the total amount of water falling on that country puts them at that absolute *water limit* right now. (See appendix B for the calculation of the water limit.) They must have average rainfall or above. An interesting thing about "average" is that part of the time -- in fact more than half of the time -- the rainfall is below average. What if the rains do not come? As the old Rajasthani lady said, "We die."

Figure 5 shows the population increase from 1970 to 1980 projected in a standard way to the year 2020. It suggests that some day in the future, around 2020, the earth's human population will exceed 20 billion people. There are arguments about what the world would be like under those conditions. With the sunshine limit put on the graph, it is clear that we do not have that much time. And if we are going to develop more efficient means of catching and using water, we have got to do it in the next 20 years or so. How fast can we mobilize the world to catch double the amount of water behind dams that we catch now, in irrigation systems, to get beyond the water limit? How fast can we do it?

We cannot do it in 20 years. Even if we passed that limit how would we get past the sunlight limit? There is no way technology can turn up the intensity of the sun. One can increase the efficiency of a plant from 4% to 5%. And maybe one can increase the part that can be used from 5% to 10%. That moves the line up a little bit more and buys another 20 years, but in another 20 years the population goes to 15 billion. Then it must be done all over again.

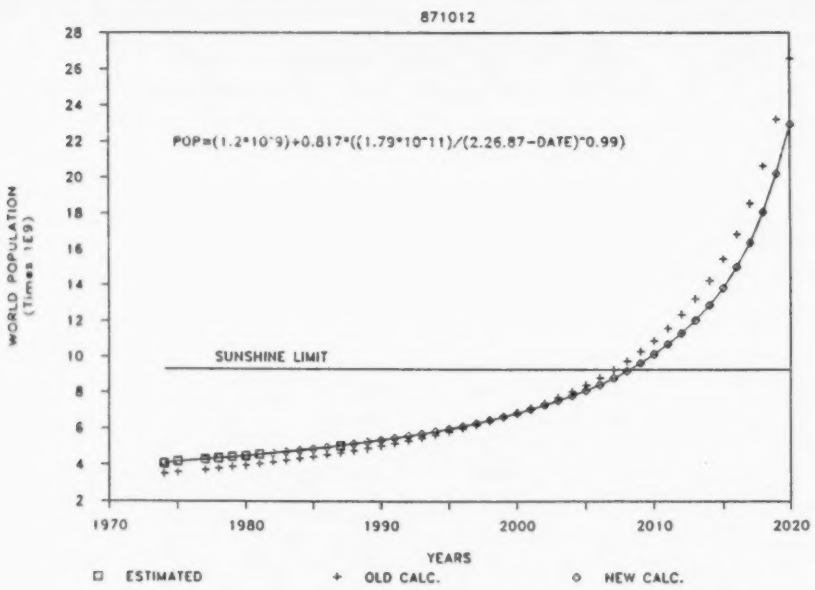

Figure 5. Population projections

Population of the earth projected by an equation that matches the record of the past few centuries quite well (pluses), modified to fit recent data (diamonds for modern equation), and compared with the limit imposed by the trapping of sunlight in food.

The difference between the environmental scholar and the developer is a very simple, small difference: the time perspective. Development is for *now*, and we who have concerned ourselves with the environment ask, "What about tomorrow and the next day and 20 years from now and 30 years from now? What about my grandchildren? What will it be like then?"

Pollution, Energy, Money, and People

Let us expand to a broader scale and show that the above questions and "how things will be" are related. There are some little equations (table 1) that one cannot argue with because they are dimensionally correct and are essentially definitions. They are simple enough that it is easy to tell whether they are correct.

If you wish to figure out how fast beer cans are being added to this square kilometer, a very simple calculation will tell you. How many beer cans per square kilometer per year? How many people are there on this square kilometer? How many beer cans do they each use per year? What fraction of them are thrown out onto the grass? Some are collected if they are made out of aluminum, so there is a removal rate. The difference between that addition and the removal is the pollution rate. Looking at it in a little broader context, we can see that to use that resource takes energy. It took energy to make the can, it took energy to make the beer, etc. It even takes a little bit of energy to drink it. So the same equation applies: The population density times the resource used per capita times the number of cans times the energy used per can plus any energy that you use just to keep cool or keep warm, to turn the lights on or to project a slide. Energy use, then, is related to the same things: population, resource use, and technology. Energy cost is a function of technology, as is waste cost.

Table 1. Pollution rate, energy use, and gross product equations

Pollution Rate (kg/sq.km/yr) equals:

	Population Density (persons/sq.km)
times	Resource Use (kg/person/yr)
times	Fractional "waste"
minus	Removal rate (kg/sq.km/yr)

Energy Use (kwh/sq.km./yr) equals:

	Population Density (persons/sq.km.)
times	Resource Use (kg/person/yr)
times	Energy Cost of Use (kwh/kg)
plus	Overhead (direct) Energy Use (kwh/sq.km/yr)

Gross Product ($/sq.km/yr) equals:

	Population Density (persons/sq.km)
times	Resource Use (kg/person/yr)
times	"Value Added" ($/KG)
times	"Respending Multiplier"

Now let us take the next step. When you go to Europe you must pay a value-added tax. The gross monetary product of that square kilometer is equal to the number of people times the amount of resource they use times the value added (as in a value-added tax). And so you see that even the gross national product (GNP) is related to population and resource use. And ultimately to energy cost. The energy cost is what it comes down to in the end.

Population, resources, and technology interact. They are all environmental concerns. They are developmental concerns and they are economic concerns and they are social concerns. Now let us see if the data really back that up. Figure 6 shows a plot of GNP for each nation versus the energy use equivalent amount of coal. If you generate about 200 watts yourself and you are using energy at the rate of 1,000 watts, you have essentially five energy slaves working for you, and that is what makes you wealthy. The average American has about 50 or 100. Roman noblemen could not afford so many slaves, but we can -- in the form of energy slaves. The distribution of points in figure 6 spreads as one goes away from the origin.

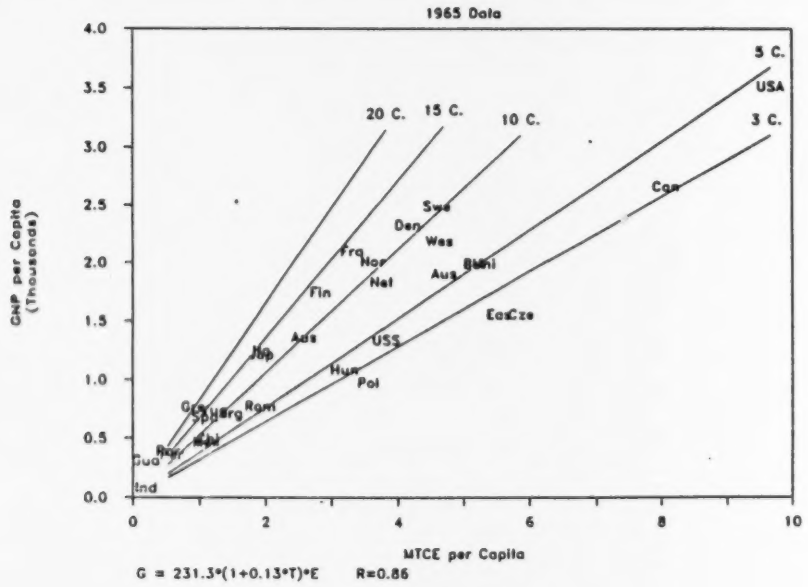

Figure 6. GNP vs. energy and temperature

1965 per capita gross national product versus per capita energy use and mean temperature at the population centroid of each nation. The equation of the lines is given. The correlation between the actual values and those calculated is 0.86.

At this point I must use a big word (you can use it on your friends, parents, whomever, so it will sound like you are learning important things at the university). That spreading pattern of points is called *heteroskedastic*. All it means is that the distribution spreads as one moves away from the origin. Economists typically will make a log-log transform so that it will not spread like that. Then it is "better behaved" and looks better -- but it does not have any meaning. A scientist looking at a heteroskedastic distribution thinks another variable has been missed. And in this case the other variable is the climate: It costs more energy to generate wealth in a cold climate than in a warm one. Equipment breaks down faster, clothing costs more, buildings have to be heated, etc. The evidence is that, per unit of energy, nations have a higher GNP in a warm climate than in a cold one. That is what the data show. Figure 6 is for 1965, and the question is whether it works that way now. The relationship has

held. Figure 7 shows the per capita national product versus the per capita energy use for 1985, and the relationship still exists. It is proportional. And of course if that is the case, then the change of energy use and the change in GNP is proportional. It is a nice, simple relationship.

There is another interesting thing on the graphs. The slope of the lines tells how efficient a nation is at generating wealth from energy. Let us take a line that goes from the origin to the U.S. over on the far side. Notice who else has the same efficiency as the U.S. The USSR, Poland, Bulgaria, Rumania, Hungary. The Eastern Block, the planned economies, the U.S., and Canada are equally inefficient. In fact, you will find that the efficiency is less among the highly militarized countries than it is among those that are not. The only way I can explain this is that the less-militarized do not throw away so much of their wealth. Because after all, the military is "throwaway." It does not produce wealth. Look at the efficiency of Japan, Norway, Denmark. They are very efficient.

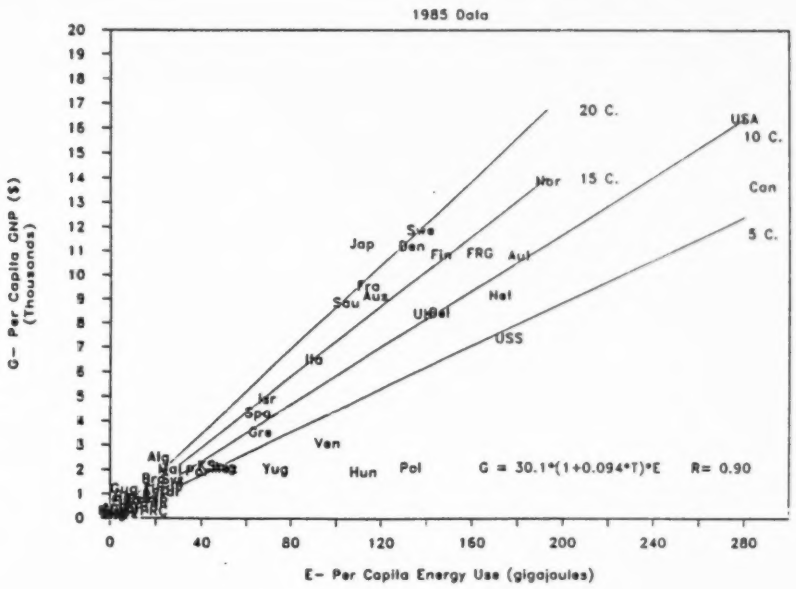

Figure 7. GNP per capita vs. energy use per capita and temperature

1985 per capita gross national product versus per capita energy use and mean temperature at the population centroid of each nation. The equation of the lines is given. The sensitivity to temperature appears to have diminished, but the correlation is slightly higher.

Food for Thought

Let us return to people and food. Here we have another simple equation. I looked at the number of people per arable hectare of land and thought that the distribution of "population-agriculture density" in these regions was related to climatic variation. I guessed what form the equation would take and calculated the population of people per arable hectare on the basis of climate and compared it here with the observed. The correlation between those two is 0.998 (see fig. 8). It is an almost perfect relationship. The equation relates population per arable hectare to rainfall and temperature; ultimately, to sunlight and water. Figure 9 is a graphic representation of the equation plotted against average temperature. If you follow

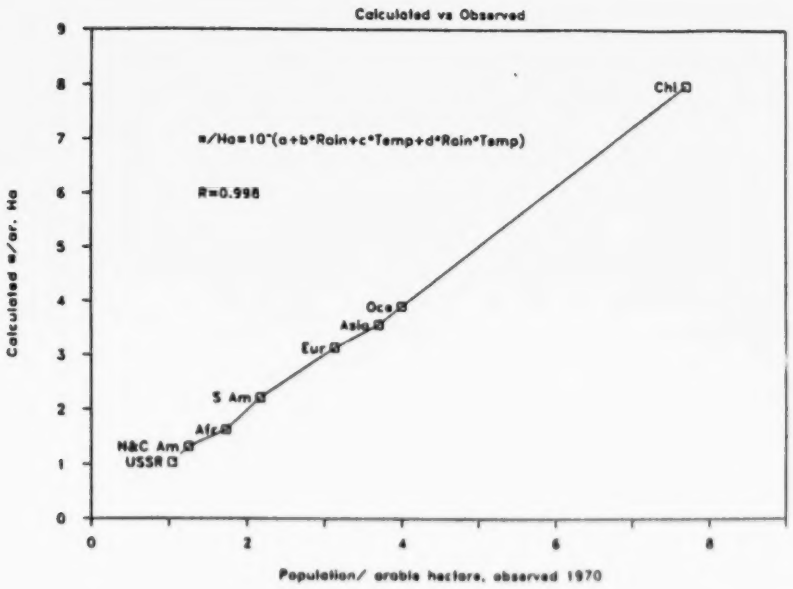

Figure 8. People per arable hectare

Comparison of observed and calculated population density per arable hectare for large areas. For smaller areas, interregional food shipments must be considered.

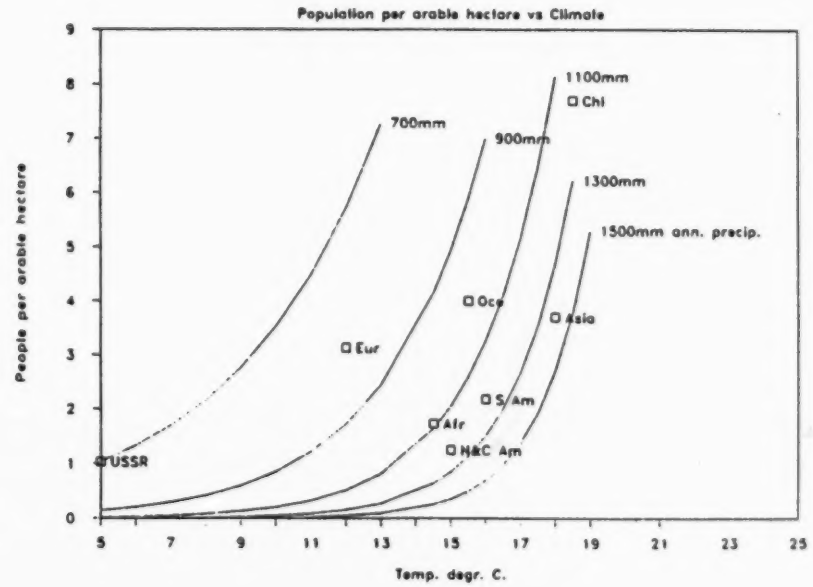

Figure 9. Food for thought

A plot of the relationship shown in figure 8. The lines represent the equation, and the abbreviations are for the regions represented by the data (Chi=China, Asia=South Asia, etc.).

the appropriate rainfall curve, you can see how many people an arable hectare feeds. The nations of the world are arrayed on the graph about as the theory predicts. That is the fact, which suggests that they are related to some simple law. The simple law is that the world is saturated with people. In the last 10 years or so, a few regions have pushed beyond the limits shown on that graph. Which regions? Africa. Where is there starvation? Africa. We need development. But in development we need to look to the future. We need to look to the consequences both *for* the environment and *of* the environmental limits.

There are opportunities for us if we understand the environment, if we understand resources, and if we understand the relationship of man to his environment. But if we do not understand these and simply forge ahead as if such limits and opportunities do not exist, then we will face tomorrow's dawn wondering whether it is a rosy one -- or a bloody one.

NOTES

1. If you are from the American Southwest, you would recognize the trees as the common, ordinary mesquite. The trees we cut down as fast as we can because they are "weeds", they are planting as fast as they can because goats can eat the leaves.

2. I like to think of the typical farmer of this region as a guy named Abel Ben Cain, both a herdsman and a farmer:

> The farmer *cum* herdsman named Abel Ben Cain
> has naught but the land, his herd, and the rain.
>
> (Unpublished Poem)

Appendix A

The Sunlight Limit

The average sunlight at top of atmosphere (340 watts/m2), less 35% loss by reflection, gives 223 watts/m2, of which plants can use about 4%, giving as biomass 8.90 watts/m2, of which about 5% (average) is edible, giving as food 0.46 watts/m2, which we use with 50% efficiency at best, giving maximum human energy of 0.22 watts/m2 of arable land.

Because people generate perhaps 200 watts of heat apiece, each person would require 899 m2 of arable land at full utilization of the sunlight and year-round cropping. If the average growing season is 180 days, the *sunshine limit* would be 5.56 persons per hectare of arable land. There are now about three persons per hectare. At present rates we should reach the limit in 35 years.

Appendix B

The Water Limit

The average sunlight intensity at the top of the atmosphere, 340 watts/m^2, will result in an evapotranspiration rate, from the typical crop plant, of 228 g/cm^2/yr, or half of that if the assumed temperature and water availability are different.

For a person using sunlight at the maximum rate for food production, this would represent, *per capita*, 1,000 to 2,049 m^3 of water per year. This means 45 to 90 inches of captured rainfall per year, or half that for an average growing season.

India receives about 5,800-6,500 m^3 of rainfall per person per year but loses about 80% in the monsoon floods, leaving about 1,000 cubic meters per person for food production.

Global Sustainability and Food Production

Robert L. Clodius

The topic of global sustainability and food production is not one that falls neatly into a single discipline, and that is reason enough to avoid it. All interdisciplinary and multidisciplinary topics are very untidy, and people who are trained in economics, as I am, do not like to deal with necessarily untidy things. We like to have things nice and neat in our little boxes, our little economic models. But we have been told to "give it a go," so in this next hour or so, I shall ask you to go along with me in this exploration in the spirit of the great Wisconsin tradition. The brass plaque up on Bascom Hall says that through "continual and fearless sifting and winnowing . . . alone the truth can be found." This evening we are going to have a little search for the truth.

What is the nature of this globe and its sustainability relative to food production? Kenneth Boulding, I believe, coined the term "spaceship earth." In some kind of chemical and physical sense, its resources are finite, but its life and the energy that supports it come from the sun. So, for as long as the sun shines, even with limited resources, human life ought to be sustainable -- other things remaining equal. And this is the cop-out phrase that economic analysis neatly sums up in the phrase *ceteris paribus*: "other things equal." Other things equal, that is, then these sorts of things follow. But, as we explore further, we will discover that other things are *not* equal.

I am sure that another of your guests, Professor Bryson, has told you that even in the physical relationships of sun and earth there is a certain instability that affects climate and therefore affects plants and animals. The tilt of the earth to the sun varies from 22 to 25 degrees over a 41,000-year cycle. The earth travels around the sun in a form that varies from a circle to an ellipse. And the earth "precesses," which means it wobbles on its axis and the ellipse lurches around the sun.

While all of these things and many more affect our climate for growing things, our sense of sustainability all depends on what sort of time scale we adopt. In the long term, none of us will be around to worry about it, but others may be. In terms of our inquiry, we must conclude that climate, derived from the earth's relationship to the sun, is pretty much beyond human control, and so we need not worry about it. The question of global sustainability comes down very much to the question of how much food for how long for how many mouths on Planet Earth.

From my resume, you have learned that I am also an economist. The word "economics" is derived from a Greek and Latin root meaning "the house" and another meaning "management." Thus, economics is concerned with the management of the house, whether that house is a household, a business firm, an industry, a nation, or indeed, the globe. We share with ecology this focus on the house, the word "ecology" being derived from the words that mean "the study of the house." The relationship between them is complementary.

Ecologists have tended to emphasize more the physical and the biological than the social. There is just more than a little intellectual imperialism at work here. People tend to have a proprietary attitude about the house, especially when it is viewed in global terms. Does the house belong to the developmental economist? He would surely think so. Does it belong to the environmentalist? In his humility he might also think it belonged only to him. Actually, it belongs to both and to neither because we must also understand the governance of the house, the politics of the house, and the customs, cultures, and peoples who live in the house if we are to be fully responsive to the questions of the sustainability of food production and the number of mouths that will be eating the food on the table.

For the obvious reason that the fewer mouths there are to feed over time, the greater the chance of their being sustainably fed, the first question becomes, "How many people are going to be living in the house?" What can we say about population? We know that the population of the earth today is about five billion persons and that it is growing. India currently has about 785 million people with a growth rate of about 2.3 % per year, which means that the population of India, *ceterus paribus* -- other things remaining equal -- will double in 31 years. Mexico currently has a population of 87.1 million, a growth rate of 2.6 percent, and, other things being equal, will double its numbers in 27 years. Kenya, a nation in east Africa, currently has 21 million inhabitants, a growth rate of 4.2 percent, and, other things being equal, will double its population in 17 years (*Population Crisis Committee* 1987). And so it goes around the globe.

People have been worrying about population and the sustainability of the globe relative to it for a long time. An economist named Malthus wrote about it in 1798 in a treatise entitled "An Essay on the Principle of Population as it Affects the Future Improvement of Society." His conclusion was that there is no hope for mankind because our capacity to reproduce far exceeds the earth's ability to produce food. The inevitable consequence, as he saw it, was infanticide, war, disease, poverty, and always hunger. Can any ecologist writing in this day exceed the picture of horror painted by the Reverend Malthus 190 years ago? "The power of population is so superior to the power of the earth to provide subsistence . . . that premature death must in some shape or other visit the human race. The vices of mankind are active and able ministers of depopulation. . . . But should they fail in this war of extermination, cyclic seasons, epidemics, pestilence, and plague advance in terrific array and sweep off their thousands and tens of thousands. Should success still be incomplete, gigantic, inevitable famine stalks in the rear, and with one mighty blow levels the population with the food of the world" (Heilbroner 1972).

Most scientists today love to point out with some glee how wrong the Reverend Malthus was. Yet, great depopulating events do take place, and many have occurred just in my lifetime: the Stalin purges, the Gulag Archipelago, World Wars I and II, the Nazi holocaust, the genocides conducted by "Big Daddy" Idi Amin in Uganda and by Pol Pot and the Khmer Rouge in Cambodia, the victims of starvation in the Sahel and in Ethiopia. Such events have not yet reached global proportions, but they have taken place in the lifetimes of most of the people in this room.

The truly notable point about population growth is that it is susceptible to human intervention. It is a people problem and thus lends itself to analysis and resolution. Something can be done to control population, and I am sure that you have read about China's efforts with its one-child-per-family policy. It is also evident that most developed nations, as they develop and their levels of income rise, develop a natural control of population growth. All of you, I am sure, realize that "control" is too strong a word to use when talking about population, involving as it does both sex and religion -- and there are no two topics on which agreement is more difficult than those. Someday people will have to wise up to the fact that population management is one of the keys to the sustainability of the production of food and of this globe of ours.

Let us now turn to the question of food production. Like population, it is also a people problem because people, working in conjunction with nature, control the supply of food. The very first thing we must recognize in discussing the future of food production, both domestically and globally, is that it is loaded with controversy -- not just a little controversy, but a lot of controversy. And it is not quiet controversy, but noisy, provocative, adversarial, denunciatory controversy, all of it probably misguided.

The rhetoric is terrific if you like rhetoric. Try this one on for size: "American agriculture will continue to prosper so long as hunger remains an international threat, agribusiness is not restrained, and established farmers with large holdings are left free to continue the pollution and soil erosion that are the inevitable byproducts of industrial agriculture. By this most logical of developments, then, we have passed from a farm-based, family-based, independent agriculture to an agriculture abjectly dependent upon many kinds of industrial interests and firmly based upon several kinds of disaster. We are producing, at an incalculable cost to topsoil and to human life and energy, and at the expense of rural communities, the land, and the streams, food to be used against the hungry as a weapon" (Berry 1977, pp. 166-167).

Now, the enemy in the eyes of many who hold these views is the production crop scientist in our colleges of agriculture, perhaps not excluding your own College of Agricultural and Life Sciences. For example, it is known that soil erosion accelerates with the planting and harvesting of soybeans. The environmentalist blames the agricultural scientist for elaborating the technical ability to increase the productivity of soybeans. The farmer plants beans using the technology when it is profitable -- that is to say, when the price is high enough. He is not compelled to use it, but because the scientists have made the production feasibility possible, it is there for the farmer to use.

The Soybean Trade Association in Washington just loves that production scientist when soybean productivity increases in the United States, but it does not want the Brazilians to get hold of our soybean technology because then we would all drown in a surplus of soybeans. Meanwhile, the soil continues to erode, the environment is adversely affected, and food production declines. The production scientist and those who argue for development tend to be optimistic in this great field of rhetoric and controversy that I have described. Their optimism is based on new research in bioengineering, new seed varieties, new technologies, new practices, and other innovations that will feed the world, and we need not worry.

I would like to suggest that there is a flaw in the analysis of both the economist and the environmental scientist, a flaw that I might add they share with demographers. That flaw is that in making forecasts about human activity based upon projections from their own disciplines, they assume that either (1) everything else remains the same, or (2) everything else adjusts so that their projections are accurate. You cannot get good, hard analysis based upon projections of that kind. Let me give you some examples.

I happen to come from a part of the country in southeastern Washington state known as the Palouse. The Palouse Hills were built of loess, wind-blown soil that produces marvelous crops but is also subject to sheet erosion. A lot of erosion is occuring in the Palouse Hills. If the rate of erosion there were projected to the entire globe, there would soon be no more soil in the hills. All of it would be down in the valleys, silting up the streams and being forced out to sea.

If we were to project the green revolution's production feasibility -- and I assume you all know what the green revolution is -- indefinitely into the future, the result would be food surpluses, not shortages. We would find ourselves, under this projection, saying that our problem is not too little food to feed the world but too much. Similarly, if we project population growth rates into the indefinite future, we are in serious trouble; but we all know that events come along that keep population projections from being realized. The reason these projections are suspect is that human intervention, whether for good or ill, is not included in the analysis. And in my judgment the answer to the question of sustainable, adequate, efficient, and safe production of food, in a manner consistent with the conservation of land, soil, and water resources on a global basis, is a matter more of culture than of science *per se*. I hope you will hear from others in these areas who will take a contrary position.

The story is told of a young college graduate, armed with all of this new technology and filled with the enthusiasm of his degree, who went into the hills of West Virginia as an extension specialist. He, of course, was from the college and was there to help the farmers. He proceeded to tell an old farmer who was sitting on the porch that he could help him by showing him how to conserve his soil and how to use better seeds, and the consequence would be increased productivity and profitability. He asked the old farmer what he thought about all that. The farmer scratched his head a little bit and said, "Young man, you can't tell me nothin' about farmin'. Why, I've wore out three farms already!"

To further illustrate, let me tell you about a project I learned of when I lived in Indonesia. This project was designed to improve the stock of the native Indonesian chickens. The poultry specialist from the U.S. brought in a flock of big heavy western hens and roosters to interbreed with the native chickens, which were lean and hungry. After a year, the production specialist returned to this remote village in the hills of central Java and -- gee whiz! -- the Indonesians were really happy to see him and told him how grateful they were to him for having brought in those heavy western breeds of chickens. "They were so delicious," they said, "so delicious!" Where were the chickens? They had all gone into the pot. The Indonesians, though, were very grateful to western culture for having brought this cargo to them. It took quite a while to figure out what had happened. The native chickens are used for cockfighting, an activity that provides recreation and an opportunity for gambling on quiet afternoons. The villagers were concerned that these fat, heavy breeds of chicken would interbreed with the lean and hungry Indonesian chickens, and the native cocks would lose their fighting ability. It would mean the end of this great recreational activity.

Such anecdotes cannot really provide the basis for testing science, but they can provide cultural information. I use them because they illustrate my point that development is much more than a scientific or economic process; it is a cultural process.

Is there a way out? How can we resolve these very complex problems? Let us examine a little bit of history. This year is the bicentennial of the Constitution. It is also the bicentennial of the Northwest Ordinance, the centennial of the Hatch Act, the centennial of the National Institutes of Health, the 125th anniversary of the Homestead Act, and the 100th anniversary of the coming together of a group of college and university people to establish the predecessor of the association that I now head.

Now, all of these are noteworthy events because they have great significance for education and for the values that we hold dear and also for the health and welfare of the nation. In looking at this history I could highlight many points, but I wish to examine only one: the concept of institution building. Building institutions, in the sense of some set of structured relationships and principles, is an almost uniquely American way of responding to new challenges.

When I refer to institutions I am not talking about bricks and mortar but rather the whole set of relationships that bring people and resources together to work on problems. The problem of educating children, whether immigrant or native-born, was solved historically by creating the institution of the public schools, and they did the job. The problems of access to and opportunity for higher education for the industrial classes were solved by inventing colleges and universities supported by the several states and by giving grants of public lands to endow such institutions -- the land grant colleges and land grant universities.

This term "industrial classes" is a quaint one that we no longer use, but those early educators tended to break society down into two parts: the professional classes, consisting of those who studied in such professions as law, medicine, and education, and the "industrial classes," consisting of all the rest of the people. Well, all the rest of the people were the important

people. They did all of the work, but they had no access to higher education because they were not going into the learned professions. So, our forebears decided that there should be established, with grants of public land to states, institutions of higher learning where all subjects would be taught, placing special emphasis on practical subjects, but not to the exclusion of the letters, arts, and sciences. These colleges were to be open and available to the sons and daughters of the "industrial classes."

The problems of producing the food to support a developing nation were addressed 100 years ago by formula grants to states from the U.S. Department of Agriculture for the establishment of agricultural experiment stations and, later, extension services.

The problems of cholera and other infectious diseases were addressed, also 100 years ago, with the establishment of a national laboratory of hygiene funded by the Congress. It began with a total budget of $300; now support for the National Institutes of Health and the Centers for Disease Control totals more than $6 billion.

When World War II broke out, it was clear that the United States was going to have to undergo a massive reallocation of resoures and that in addition to tanks and planes and ships and guns, the country would require an all-out effort in the production of food and fibre. The slogan tossed around at that time was "food will win the war." Because of the vision of dedicated men like Senator Morrill in the creation of the land grant universities, because of the foresight of a congressman from Missouri name Hatch, because there was in place a cooperative extension service, and because of the wisdom of the states and the Congress in funding these enterprises, farmers were able to produce all the food that we and our allies required. They were able to draw on the prior investments that had been made in teaching institutions, in research, and in extension services.

Problems of health received increased attention after World War II. Because Congress had already created the National Institutes of Health and had supplied support for university health centers across the country, and because they had also established federal research facilities such as the Centers for Disease Control, the universities were ready with trained personnel, and laboratories and equipment were available to make possible the subsequent quantum leap in medical science. That leap came because the institutions were established and already in place and because there were friends in Congress working together on a bipartisan basis. They saw and appreciated the need to support on a continuing basis research in all of areas of medical concern. Now those institutions are there when we need them for basic research, but also when such crises as Legionnaires' Disease and AIDS arise. They continue to address all of our chronic health problems, including cancer and heart disease.

So I would say that building and maintaining institutions is the way to insure that there is a social infrastructure with the capability and capacity to solve problems.

It seems to me it is in these last words that we find the key to global sustainability. Capability and capacity. Capability and capacity to produce food. Capability and capacity to keep populations under control. The house, our globe, can be managed if we continually develop capability and capacity.

Some say we should return to a simpler world, a low-input world, with organic agriculture, horses and mules, or whatever. Not only would this be resource-conserving, but it would also help reduce crop surpluses. Now, if you have ever farmed with horses and mules, you would think this a lousy idea. I grew up in the wheat fields of southeastern Washington at a time when we did farm with horses and mules. To pull our combine around the field we had to hook up 27 of these draft horses and mules in strings of six with three leaders. Things worked out pretty well, but every once in a while a couple of these mules would fall in love. The result

was the darnedest round of horses facing in the wrong direction, with plenty of broken harnesses and hitches. And if you have ever had your foot stepped on by a horse or mule -- it hurts like hell. Anyone who has been through that would never want to go back to farming with horses and mules or to this somehow-or-other simple agriculture. I do not mean to ridicule well-meaning people who already have their solution in hand, but I cannot believe that regressing to a Jeffersonian agriculture is the wave of the future. Nor do I believe that a "damn-the-torpedos, full-speed-ahead (forced draft, flank speed)" solution is appropriate either. I do believe that we must conduct research and enhance the capacity to produce food while controlling population and developing the capability to manage it all.

Developing capability and capacity does not mean they have to be fully utilized all the time. Utilization in the short run can lead to production surpluses of food. Indeed, that is what we have in the United States at the present time. Similarly, we understand that full utilization could lead to runaway populations and food deficits around this global house of ours. So we need planning and management. As far as I know, the human animal is the only one that thinks about and plans for succeeding generations. For all other animals, "planning" seems to be only an instinctive process that insures the survival of preferred genes.

The obvious institutions that are currently available to at least begin work on questions of sustainability are the state universities and the land grant colleges. If adequately developed and supported, they could develop this capacity to research and understand the problems that we are addressing. They have colleges of agriculture, colleges of the humanities and sciences, colleges of engineering, and schools of law, all of which are necessary as we try to bring together this host of extremely complex subjects into some kind of integrated whole. And if it is really important to do -- and I think it is -- it will require great chunks of money. It will need to get that money from the federal government because surely the problem of global sustainability is not a state problem.

We come, then, to the large question. What are the prospects for adequate federal program support? Let's take a look at the federal budget that has been proposed by this administration. It is a $1 trillion budget -- a thousand billion dollars. About 140 billion is interest on the federal debt. We cannot do an awful lot about the interest; it has to be paid. So about 14% of the budget is beyond our control. The next item we call "contract obligations." We cannot do much about contract obligations except fulfill the terms of the contract, and so we lose access to another 18% here. Adding these up, we find that there is 32% of the budget, about $320 billion, that we can't do anything about. Another $450 billion, about 45% of the budget, consists of entitlements. These are programs whereby Congress dispensees funds to particular individuals in our society. One of these entitlements is Social Security. Another one is Medicare. Another one, perhaps of more interest to you, is Guaranteed Student Loans. Agricultural supports also fall into this category. In theory, you can do something about these entitlements; but remember that we are talking about politics -- and politically, if you touch the entitlements, you don't get reelected. There is good reason, then, for saying that not much can be done about those. If we add all of these, we come up with about 77% of the budget, or some $770 billion, that is largely uncontrollable. This leaves us with $230 billion, about 23%, that ought to be in some sense controllable. But $140 billion of this is military, and you can imagine how controllable that is. So we get down to $90 billion, or about 9%, which we call "nondefense discretionary items." (Office of Management and Budget 1987) Everything that is important for the subject we are addressing this evening comes within this 9% of the budget. The issue is whether we can get enough out of this small fund of nondefense discretionary moneys to address effectively the problems of capability and capacity with respect to the sustainability of agriculture around the globe.

The answer to the question of the objects of expenditures -- in cynical Washington, D.C. anyway -- is sometimes given in these terms: some is spent on liquor and sex; the rest is spent foolishly. Well, we can never be certain how much liquor and sex is involved in this, but we

can be sure that much money is spent foolishly. To give you some notion of the foolishness of all of this, the rounding errors that are used in presenting the budget are on an order of magnitude of $100 million. So if the program in which you are interested is smaller than $100 million dollars, it does not even show up.

Let's pursue the politics of the issue a bit more. We have a president who will not cut the military. We have a president who says he will veto any tax increase. We have a Congress that is confronting its own Gramm-Rudman-Hollings constraints, which compel reductions in the budget deficit. With these things given, what are the prospects for a substantial increase in the research funds needed to study the sustainability of food production on a global basis? Here is where I get extremely pessimistic.

Certain ideologies now embraced by the White House make it very difficult to address on a global basis the issues we are thinking about. One of these fixed ideas is that free market forces can solve all problems such as this, so we do not even need to talk about it; the market will take care of it.

Another is that capitalism is the only acceptable form of economic and social organization, and everything else is bad. In thinking about global sustainability and the production of food to meet global population needs, I do not know how you can afford to say outright that a political system is bad and unacceptable and you will not work with it. We are talking about the whole darned globe. We are talking about Spaceship Earth, and such attitudes are really inappropriate.

Another one of these ideological positions is that what is best for the individual is best for the society as a whole. You see where that leads: If everyone is at complete liberty to do whatever he or she wishes, the aggregate effect can be highly undesirable for the society as a whole.

Another ideological point we hear is that the individual is best served by "getting the government off of our backs." Again, you can see where this might lead.

Global sustainability cannot be assured by the free market in and of itself. What is the economist's model of the perfect market? It assumes large numbers of individual buyers and sellers, individuals so small relative to the total that they have no influence on the whole market. The products in this theoretical market are homogeneous; they are not differentiated by color, shape, substance, whatever. The model also assumes easy entrance and exit of both producers and consumers. The buyers and sellers have complete knowledge of what is going on in the marketplace, and the market price resulting from such knowledge determines what people do and what they decide to produce, what people buy and how much they consume. So all of the important economic decisions, and all of the important social decisions that relate to them, are based on the market price. You can all see that this is a perfectly beautiful theoretical model, but is it an appropriate model for the global food market?

It is obviously not an appropriate model in the short run, where we have the world's food trade dominated by relatively few sellers and where those relatively few sellers are either large private conglomerates or governments themselves. Obviously, it is not an appropriate model for determining the long-term costs of conserving the soils of the Midwest, or the soils of the Palouse Hills, or, indeed, the tropical forests of Indonesia.

Economics does have something to contribute with its concept of the rate of interest. The rate of interest we can view as a payment for not consuming -- for conserving, for saving. I think you can see, obviously, that it is a great concept for the rich and irrelevent to the poor. Income is not evenly distributed across the country or, indeed, across the world, so its impact is differential.

I conclude that building an ideal model and then trying to make it fit our reality is not a very fruitful endeavor. Perfect economic models do not function in the real world of farmers, consumers, politicians, scientists, environmentalists, philosophers, nations, and religions. rather, we should be good natural philosophers and followers of John Dewey, who addressed problems by developing and enhancing our capacities to deal with them. Such an approach is appropriate to the problem of the sustainability of global agriculture.

Let me close by reciting some poetry from a man who was born almost 400 years ago. It speaks to all of us, I think, as we contemplate this future. I am sure it is familiar to you.

> No man is an island, entire of itself; . . . any man's
> death diminishes me, because I am involved in mankind;
> and therefore never send to know for whom the bell tolls;
> it tolls for thee. (John Donne)

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The Red Queen Syndrome: Running Faster -- Going Nowhere?

John E. Ross

It is as obvious as "the nose on our collective face" that (1) increasing world population, (2) increasing per capita demands for resources, and (3) increasing dumping of wastes are putting immense pressures on our resource base. There is no consensus on the general risk that we face as a result of this increasing pressure, although specific risks are quite obvious. Many variables are at work. But we do not need a precise understanding of general risk to examine and act on the general issue of sustainability. Tonight I would like to explore two underlying questions regarding sustainability. The first asks whether we are consuming too much and too fast. The other asks whether we are wasteful and inefficient in the way we use resources. Both have to do with the metaphor in the title of my lecture: the Red Queen Syndrome.

In "Through the Looking Glass," Alice expects, as do we all, to get somewhere if she runs very fast while working very hard at it. The Red Queen, however, insists that you have to run very hard and keep running faster just to stay in the same place. The Queen drags Alice along by the arm, running faster and faster. In that world on the other side of the looking glass, the Red Queen seems to see things more clearly than does Alice, for when they stop to catch a breath they are still at the starting point. Maybe not even at the starting point; to have a starting point, you obviously have to be going somewhere!

But let me back up before I get more thoroughly attached to Lewis Carroll's writing style than is reasonable. With the title of this lecture -- the Red Queen Syndrome -- I have obviously suggested a metaphor. *Maybe we are running very hard and not achieving what we think we are. But if that is true and if we are all Alice -- who then is the Red Queen?* Who is it, or what is it, that is urging us to run faster to stay in the same place?

Perhaps, however, we are getting somewhere. Maybe Alice was having a bad dream or just a momentary loss of confidence. But if our attempts to get ahead really are an illusion; if we are running harder and not gaining; or even if we are running at a steady pace and the landscape is also on the move, but in reverse, sliding away behind us; then, like Alice, we ought to stop for at least a moment, sit down in the shade of a tree, have a big drink of cool water, and ask some questions.

That, of course, is the purpose of this forum: to take some time out in the middle of the summer to ask some questions. The title of the forum is, you recall, "Environment and Development: Building Sustainable Societies." This title gives us at least some clues to the nature of the race we are in, if not a clear identification of the Queen. Let us look a little more carefully at the words in this title.

Let's start with the word "development." Lifted out of the context of the title, it defines, more succinctly than any other word I can imagine, the public mood of the 20th century. Usually we attach an adjective to the word: *economic* development. Now we can see it more clearly. Not only is a race on to develop resources for economic purposes, but the race is increasingly competitive. There are others in the race, thus there can be winners and losers. The Japanese are surely ahead of us this evening in computer chips. The Russians are surely ahead of us again in the space race. The Brazilians are edging up on us in the production of soybeans.

More subtle but just as important is the idea of the *process* of economic development -- in particular, the fact that research and technological systems precede development. In fact, development now seems quite impossible without basic research and complex technology. Take, for example, the advances in superconductivity in recent months. Superconductivity, the process whereby electricity can be made to flow and flow and flow without frictional loss of energy, has until just recently been possible only at extremely low and, economically speaking, impractical temperatures. That is all changing now. Even Madison, the city of four lakes, the Athens of the Midwest, we conclude, will become a world center in the development of superconductivity, and economic development in Dane County will expand because of that. Have kilowatt, will run -- and run, and run, without getting all heated up. We may even be able to develop fusion of deuterium and tritium, forms of hydrogen, at room temperature.

Our pace quickens through all three phases: through research, through technological application, through economic application. The outpourings of research, in fact, seem to run ahead of technology and development. We conclude that we *must* take advantage of what we learn -- otherwise there is waste. We further conclude, at the other end of the process -- at the end of the development rainbow -- that a better life awaits us, a life more rewarding than the one we are leaving behind. The scenery will be new, more pleasant, more secure.

Now let us look at the word "building." This word implies that we have moved through this 20th century with boundless confidence in our ability to build better societies -- societies that reduce our risks and improve our standards of living, however you choose to define a standard of living and whatever you select for improving *your* lot. We have certainly come a long way in those regards. We have conquered small pox, diptheria, and typhoid. Children survive these diseases and grow up with an education. Water supplies are safe or can be made safe. We have the amazing ability to travel all over the world. You and I can experience firsthand the multitudinous cultures that exist. We have figured out how to survive in Wisconsin in January with some degree of comfort and have time left over for cross-country skiing. We are not hungry this evening. In the morning we can go to the farmer's market and, for a pittance, claim July's earthly riches brought together for us on the Capitol Square. With superconductivity and room-temperature fusion of hydrogen we *will* have more abundant supplies of electricity than we have ever had before -- and it will be delivered to us more efficiently from greater distances.

But the framers of this forum included two more words in the title: "environment" and "sustainable."

Environment, in the technical sense, is not such a difficult word. It refers to the natural world. It is nature's economy. We do impose our economy upon the natural world and, in the process, create elements of a synthetic environment, but our environment is still circumscribed by nature's laws, if not nature's history. We do not yet live in a truly synthetic world, although we are taking a major step in that direction right now, with biotechnology. Though *we* are not yet synthetic, we have clearly accepted the premise, as an integral part of development, that we should run fast and work hard to further understand nature's laws and nature's economy. You are running hard, aren't you, for a college education? And the diploma will be proof that you have gone somewhere.

We must remember that we run such races with the general understanding that they are invariably geared into the process of development. Even our environmental concerns focus on such concepts as efficiency in the use of resources, the recycling of wastes, the carrying capacity of the environment, and rates of depreciation of the future value of resources -- all of which are indices designed to enhance the path of development. They are designed, in fact, to clear the debris from the track so that we can run unimpeded.

Now we must face up to the more difficult word in the title of the course, the more ambiguous one: "sustainable."

At first glance the word is heavily anthropocentric, that is, human-centered. Sustainable for whom? For us, of course! We must take care that we do not heedlessly foul *our* nest. We must not *waste* things. We must take care that we are parsimonious in the use of resources so that there is enough to go around for this generation, and enough for the fourth leg of this relay race, the fourth generation down the track, your great-grandchildren, who will be enrolled in this university in the year 2050. How else could you interpret the word "sustainable" when it is linked to the idea of societies? "Sustainable societies" was the mandate given to us when the title for our forum was chosen.

But, as we know, there is another meaning lurking in the word "sustainable." "Sustainable" may imply that Alice sat down where she should have, which is where she started, because it is better than where she would have ended up. And maybe she sat down in the nick of time.

As we examine the concept further we may find that, in our increasing haste to get somewhere, the place from whence we started has slipped away from us. Now isn't that something to think about? Maybe we are destroying the ozone layer -- creating a more dangerous rather than a better life "through chemistry." Wouldn't that conclusion be a challenge for the human race as we approach the end of the 20th century and begin the 21st? What kind of technology and how much in energy costs will it take to restore the ozone layer? Will we need to *manage* the ozone layer for a sustained yield? Can we introduce ozone into the stratosphere? Or develop a synthetic shield? Or even trap the incoming ultraviolet and remove it as a 21st century resource? "Sustainable" might even mean not merely a prudent and deliberate forward course of action, but a retreat from some general rate of development. If we do have to make a retreat, we can only hope that it will be an orderly one and not a rout.

I conclude that societies, at least some of them, have accepted the concept of sustainability to mean an environment that is safe as our habitat and permissive of increased economic development. That acceptance, however, implies a steady increase in the amount of management required. This may be the most important conclusion of this lecture. A key element in our race is increased management: management to protect water bodies and forests from acid rain; management to clean up and protect ground water from toxic wastes; management to operate, dismantle, and store the products of nuclear power plants; management to bring in line in an orderly way new categories of resources as we deplete the current ones. In other words, management for sustained yield.

But sustainability also implies environmental stability, and that could necessitate *less* management: less management of tropical forests, less management of the troposphere, less management of groundwater. We might consider less management for three reasons.

First, in the sense of a broad benefit/cost analysis, we might be better off not having to pay the cost of managing the quality of groundwater or managing the quantity of ozone in the upper troposphere. It will be exceedingly expensive to clean these things up or maintain them as they get polluted. Those of you who follow *Science* magazine may have read last week's story about the grossly clumsy management of atomic wastes at the Hanford plant in eastern Washington. It will take billions of dollars to clean up this mess, which has been penetrated by burrowing jackrabbits and deep-rooted tumbleweeds. So why not avoid such costs by *constraining* the use of those things that pollute ground water or the troposphere?

Second, we can muck things up badly in our increasingly complicated management schemes. Chernobyl is nature's not-so-friendly reminder of that. Chernobyl was an engineering failure. So is Hanford, and it is, I dare say, as bad as Chernobyl.

Finally, there is the possibility, remote as it may seem, heretical as it may appear, that things might be better with less development, or with selective development, or with radically alternative approaches to development. Things might be better if we were more *conservative* than we now are. That might be the conclusion of a reevaluation of our approach to sustainability. Yet, less development seems like a copout; it seems like a compromise in the race of human intellectual achievement.

I conclude that, on balance, societies have not yet come to grips with this concept of environmental stability through less management, although Aldo Leopold suggested it as a position worthy of our consideration 40 years ago.

Let's continue asking questions, but now let's change the direction of our analysis and approach Alice's fast-paced race from another direction. Some have said that we are the "fortunate generation," by which I mean the "generations" represented in this room. We are the fortunate generation, it is said, because we grew up after the discovery of penicillin and before the oil ran out.

To test the idea of whether we do live in a fortunate time that could be coming to an end, let us focus on oil for just a minute. Oil does tend to grab you by the heart. It is the liquid in the arteries of modern society. I know what some of your responses will be to this example, so I will immediately offer a counter-response. It is true that there are alternatives to oil as an energy source, but it is also true that we have made immense capital investments in oil research and recovery and industrial economies -- whether market-oriented or centrally planned -- remain addicted to that singular resource *and* to the capital investments inherent therein.

Geologists and government officials argue about how much oil is left to be found and economically pumped. Optimists point to fields in Mexico that have delivered substantially more than expected. Pessimists focus on the multimillion dollar exploration projects off the Atlantic coast of the United States that have turned up virtually nothing. Listen to this fact: The United States spent $250 billion on domestic petroleum exploration between 1980 and 1984, but proven reserves of crude oil dropped almost 5% during that period and a total of 27% since 1970.. Again in *Science* magazine, two weeks ago, an article on U.S. oil reserves declared that recovery from existing major oil fields in the U.S. has been running higher than expected. The article reinforces my statement rather than refutes it, however, because it points to the increasing costs of recovery. Nevertheless, these figures do give some modest hope for increased capacity over perhaps the next decade. If ever there were an example of running hard in place -- or slipping behind -- then this is it.

Let's face it, let's face it this evening, the United States clearly is on the down side in petroleum production. We have an estimated 5.6 billion metric tons of oil reserves. We will run very hard in the next 20 years to squeeze out the remaining domestic oil, and we may build the reserve up to 6 billion or 6.5 billion metric tons. It will be increasingly expensive to do so. We would face national disaster if we get caught short in oil supplies and a major crisis develops at any time during the next two decades, the time period of increasing scarcity of oil. We will need, as never before, geopolitical stability in the next 20 years. Day by day, night by night, we will need stability in the Arabian Gulf (I am using the term Arabian Gulf, rather than Persian Gulf, very deliberately; while Iranian oil is important to us, it is not as important as Arabian oil). The Middle East, more specifically Abu Dhabi, Dubai, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, and Syria, has an estimated reserve of 54 billion metric tons -- 10 times that of the U.S. The Exxon Corporation concludes, however, that declining reserves will soon be a worldwide phenomenon. Oil production, the company calculates, will reach a plateau early in the next century and then begin to drop.

Many market economists would not be alarmed by this obvious set of physical and economic circumstances. They would first point to the fact that industrialized nations reduced their oil use 19% between 1979 and 1985 -- a direct result of the price increases. However, in 1985 oil still accounted for almost 43% of primary energy consumption for the industrialized nations. And with oil prices falling in the most recent years, you would expect petroleum demand to increase. It did. In the first eight months of 1986 it increased in the U.S. some 2.1% from the same period a year earlier. That seems like a modest increase. But if demand were to expand by 3% two years in a row, U.S. petroleum consumption would rise about one million barrels per day, or about one-fifth of U.S. oil imports in 1985. Any increase in demand, in this economy or in any other, advances the day when oil will come from a single region of the world -- the Middle East.

Petroleum remains an unaffordable luxury for more than half the world's peoples who cook and heat with fuelwood, charcoal, animal dung, and crop residues. Those sources of energy, while available, are not exempt from the issue of environmental stability, and thus sustainability. Fuelwood comes from forests. Animal dung and crop residues, if burned, are not returned to the soil. Yet, to the extent that nations do industrialize, they increase their demands for oil.

At this point you may say, "So what? There's natural gas." The Russians have made some phenomenal discoveries of natural gas in the last couple of years and claim their reserves will last through the 21st century -- assuming they consume what they produce. But they will not hold on to it for themselves. They will ship it to Western Europe, which is essentially without oil or gas reserves. I can imagine a gas pipeline across the Bering Straits, hooking into a pipeline in Alaska. I can imagine another artery down the Kamchatka Peninsula flowing into Japan. The Russians will ship gas because they continue to need hard currency -- for development of course.

Incidentally, world consumption of natural gas jumped 79% between 1975 and 1985. The World Bank reports that about 50 developing countries, including 30 that now import oil, have natural gas reserves, but they have not organized systematic exploration or development, in large part because of the high cost of building a gas distribution system. The bank surveyed 15 developing countries with sizeable gas reserves and found that their average current production is only 16% of the level that proven reserves could support. The bank projects a four-fold increase in natural gas production in developing countries by 1995, just eight years from now.

What about coal? North America has an estimated 263 billion metric tons of coal reserves, constituting 28 percent of the world's reserves. There is now no doubt: Coal is the key energy source of the next generation, the generation that will be born in the next 10 years, particularly in the United States. Your kids!

And then there is nuclear fission. Worldwide nuclear electricity consumption rose 99% between 1980 and 1985, with the largest increases in France and the Soviet Union. Much of this increase is because plants begun several years ago are finally coming on line. The number of new plants being constructed is now, however, in decline. West Germany, for example, has ordered only one nuclear plant since 1975, and construction has not begun on eight units ordered before then, largely because of political opposition. In the United States, utilities abandoned more than $18 billion of investment in 113 proposed nuclear reactors, largely because of cost overruns and because of lower-than-expected demand for electricity. $18 billion? The Red Queen is smiling. The demand for electricity is not decreasing. Rather, it is a *lower-than-expected increase* in demand.

Six newly industrialized countries -- Argentina, Brazil, India, Pakistan, South Korea, and Taiwan -- are operating a total of 18 recently opened reactors. So at least some of the developing countries have begun to make the nuclear commitment. What we are seeing in nuclear technology is a ripple effect, like an expanding ripple on a pond, fading in the center, but

moving outward in an expanding ring. That ripple phenomenon may be true in other technologies as well. They have not worked so well in the societies that originally developed them, but they still have a function in other societies that are now rapidly accelerating. On balance, there is at least some evidence that the nuclear runners, at least the fission runners, are getting overheated and that there could be a resultant slowing of the pace.

There is a tendency to get fascinated with the data on energy and lose sight of the real issue of sustainability. So let's return to the issue.

I firmly believe that, for at least two major reasons, we will work our way through the reserves of fossil fuels (oil, natural gas, and coal) and will deplete these resources. First, they are a concentrated source of high-quality energy, a bonanza of giant proportions that we have inherited from geologic history. Second, having made the vast capital investments to get them, we will work the deposits to get the return on that investment. Over what time period will we harvest the prosperity they generate? Perhaps 300 years. But remember -- half of that time has already elapsed. If we think of fossil fuels as having elevated the carrying capacity for humans, and they have, then we would at least consider that the carrying capacity would drop back down when they are gone. There is evidence of a similar expansion and contraction in Europe and the Mediterranean Basin in the 14th and 15th centuries, a time when wood was the primary industrial fuel and the forests were rapidly being depleted. Fossil fuels, without any question, remain the foundation of our industrial, technological society. And fossil fuels, including uranium, are, again without any question, depletable.

Fossil fuels have environmental costs. If we are honest with ourselves, if we are not naive beyond imagination, we will subtract these environmental costs from the economic benefits. And we will do so not in some final summing up near the end of the hydrocarbon era, not in some historical review of the 20th and 21st centuries, not a hundred years after that, but each and every day we use them -- particularly as we enter the era of coal. We inevitably approach an energy transition, whether orderly or chaotic. Without an orderly transition, the observations of the Red Queen will dominate. But it may be hard to find a shade tree.

How long the hydrocarbons and uranium actually do last is obviously a function of the supply, but also of the demand. Demand is a function of three things: (1) the population, (2) the ability to purchase, and (3) the success of technological systems in discovery and delivery (or, in other words, the efficiency coefficient). This definition does not include needs and desires, but we will return to those later. These three items -- population, ability to purchase, and technological success -- are variables.

Population numbers really are the bottom line in considering the sustainability of societies. Population numbers define the bottom line because there is a per capita minimum demand for water, food, shelter, survival. The most singularly impressive fact of our time is the increase in population. Population is increasing (1) because of our increasing ability to exploit resources and (2) because of a decline in the death rate. World population is passing the five billion mark probably right about now -- at least before the end of 1987. The population of the developing world is increasing at the rate of 2.4% per year (2% if China is included, and China cannot be ignored!). The annual population growth rate in the developed world is about 0.6%. In the Third World, a woman bears an average of five children. In the industrialized world, just under two children per woman is the norm -- a number that is below the replacement level.

Although the overall growth rate is declining, a conservative estimate projects another three billion people by the year 2025, 38 years from now. Ninety-five percent of the increase will be in the developing countries. One hundred years from now the population of what are now developing countries is expected to reach 8.8 billion, compared to 1.4 billion in the currently developed regions.

In sheer numbers, China and India dwarf all other nations with their current populations of 1.050 billion and 785 million respectively. One could almost conclude that the issue of global sustainability will be settled in those two countries. Perhaps it will, particularly if Indians and Chinese set out on major waves of migration. They have before. But the highest growth rates currently are in Africa and Latin America. Between 1985 and 2025, Africa is expected to increase its share of the total world population from 11.5% to nearly 20% Increasing population lends credence to the metaphor: running very hard and staying in place. A country with 2% population growth faces an almost impossible development task.

Again, it is very easy to become immersed in the numbers and lose sight of the issue of sustainability. For populations, at whatever level, sustainability is a function of food production. The key, of course, is *per capita* food production. Between 1965 and the present, production per capita increased 7%. That is encouraging as a raw figure, but we have a long way to go in meeting nutritional needs. Africa's net yields of agricultural products, running less than one-quarter those of Europe, have declined 5% in the past decade. We can conclude that, worldwide, we are edging up in food production. India does have reason to be sanguine, at least in the approaching years. Clearly, however, the big population challenge lies ahead, and the most challenging period come when world population reaches eight billion and fossil fuels are much more costly than they are today.

Clearly, subsistence agriculture alone will not allow the developing countries to stay in place, let alone keep up, if for no other reason than that the rates of migration to the cities are rising. The agricultural infrastructure will vary from one society to another, but the key issue is not crops for export, but crops for food. We cannot run very far or very long if nutrition survival depends on foreign grain. I would add one caveat here, however: We may well adjust what we mean by "foreign grain." For example, we may relocate the distribution of grain production in North America as a function of available water, balancing the productive capacities of Canada, the U.S., Mexico, and even Central America. The key point in this realignment -- this potential for a North American common market -- is the unalterable fact that Mexico is water-limited.

There is, of course, another factor in the population equation: the possibility of change in birth rates. Much useful work has been done in investigating the social, economic, political, and cultural factors that influence population growth and decline. In general, high birth rates are found where mortality rates are high, where household labor is the key to agricultural production, and where children are essential to the well-being of parents in their old age. Falling birth rates, on the other hand, are normally found when educational opportunities for women and children increase and when women move from unpaid family labor to paid employment. Thus, we have some clues concerning the changes in birth rate that lead to sustainable development. But to provide such conditions, we need to talk, fundamentally, about economic growth for these countries, growth that will give more security to women and children.

To address this issue we need to examine for a minute some basic facts about the developing countries' ability to follow the energy pathways established by the industrial nations. On average, a person from a developing country consumes less than one-sixth the commercial energy used by a resident of an industrialized nation and less than one-twelfth as much as the average U.S. citizen. Of the current five billion people in the world, about 3.8 billion live in the developing countries. If we were to replicate on a worldwide scale the U.S. economy as now constituted, we would need to increase by a magnitude of *12* our use of energy, some 92% of which is now oil, natural gas, coal, and nuclear (the major other source is hydroelectricity). That figure is based on today's consumption rates. Looking at tomorrow and taking population growth into account, the volume would have to increase over the next 40 years by another 60%, or a *20-fold* increase. This would clearly be difficult to do, although perhaps not impossible.

Such a breakthrough might occur if we could link superconductivity to solar-generated electricity. (Both seem possible from a technological standpoint. One would need a massive "scaling-up." There is at least the possibility that some of those so-far elusive structures permissive of superconductivity are, in fact, rare natural materials. It would certainly be ironic if the most valuable deposits of newly valued mineral resources were in the Arabian Gulf countries, with none in the U.S., Japan, western Europe, or Russia. The balance of power in the North/South debate might be reversed.) But if we had a 20-fold increase in energy production, regardless of who had the resource advantages, we would still just be running in place -- albeit at the U.S. pace -- without some *additional* rate of development in energy supplies. The Red Queen would again have been more clear-headed than Alice.

I admit that I have constructed a difficult scenario here by patterning the world after the U.S. and assuming no decline in birth rate. But I started this lecture by stating that we wanted to identify who the runners are and who is setting the pace, and so I think the scenario serves as a legitimate point of discussion.

The task of increasing energy supplies beyond those required for running in place assumes several things about carrying capacity. And please note: I am talking about possibilities, not probabilities, and not goals.

The first issue is whether there is still room to flex our developmental muscles, to move ahead with utter confidence. Development room would come from gathering in more of the potentially available resources or by using more efficiently the ones already available. Let's take just one example in the latter category. The evidence is convincing that more water could be used to irrigate food crops and that such water for irrigation could be more efficiently used. I am very much aware of the desertification or salination problems in the more arid regions and the resulting declines in carrying capacity, but maybe we need to consider all that water pooled up in the Great Lakes, or water that could be diverted from rivers that now flow into Hudson's Bay, or from Lake Baikal in Russia -- not just the water in the Nile, Niger, or Colorado rivers.

Do not assume that I am suggesting the water-enhanced intensification of grain production in North America and Russia for shipment to Central America, Asia, or Africa. I am suggesting that more people might be located where water and arable land are geographically combined, resulting in major increases in food production and short supply channels. I am conscious here of Bryson's rainfall limit to growth; but as an irrigation farmer, I also know that we could probably quadruple the efficiency with which we use the water. Having lived some precious years on the high desert of eastern Oregon, I do know what can be done with irrigation water and that you can be careless or parsimonious in the way you use it. In the future, we could and likely will "manage" water on a much grander scale than previously conceived. And we will do that in areas that are now water-plentiful, such as the Great Lakes basin. We might build a network of Martian canals on Earth!

The key point here is that carrying capacity is not fixed. It is variable. Since it is variable, it can go in either direction. So we ought to talk about the possibility of declines in carrying capacity. Declines, I conclude, can result from three causes. Two of these are clearly related to human behavior and are thus susceptible to changes in behavior. The third is naturally driven and may or may not be susceptible to changes in our behavior.

First, the human-related downers.

The first category involves the stuff we dump into the environment. I hinted at this earlier when I mentioned the impact of fluorocarbons on the ozone layer. Ozone depletion could cause a global decline in carrying capacity as increasing amounts of ultraviolet radiation penetrate into the lower levels of the atmosphere, affecting animals -- including us -- but even more

important for sustainability, affecting plants. As a problem, this is reasonably tractable. We can ban a family of chemicals without much turmoil. (There is, however, always some gnashing of teeth. The current argument is whether fluorocarbon emissions should be lowered or permitted at existing levels.)

Carbon dioxide is in the same general category. A buildup of carbon dioxide in the atmosphere could cause a global decline in carrying capacity. In fact, some people believe the ongoing Sahelian drought is an early symptom of the human-caused buildup of carbon dioxide. There are scattered newspaper reports now about a drop in the flow of the Nile below the carrying capacity demands of Egypt, possibly linked to carbon dioxide increases. If true, the newspaper reports will become more than scattered. Carbon dioxide, however, is much harder to ban that fluorocarbons. Carbon dioxide is harder to ban than DDT or other specific pesticides. Carbon dioxide is even harder to ban than the long-lived radioactive wastes of nuclear power plants. In fact, it is impossible to *ban* carbon dioxide -- and ridiculous on the surface of it. After all, we cannot ban combustion, including human breathing. But we could, had we the will, *limit* carbon dioxide emissions.

The second human-related category of carrying capacity depressants may be a little more difficult to handle. It has to do with the rate of depletion of resources -- both renewable and nonrenewable resources. Earlier I spoke of the depletion of fossil fuels and concluded that they will indeed be depleted. The same will be true for many metallic ores (but we need to be careful on this one; we are entering the age of ceramics, and silicon is an abundant material). But now let us consider the depletion of resources generally and the impact of that process on carrying capacity.

We Europeans have had considerable experience in that regard as a result of the occupation of North America over the past 400 years. We have not gone as far in "managing" resources as our relatives who stayed behind in Europe, but I think you have to conclude that we have come a long way here in North America, and we are headed in Europe's direction. Rene Dubos was a prophet in that regard. The Netherlands and Switzerland may well be the models for the 21st century. Obviously, not all the chapters are written for North America, and, in terms of carrying capacity, there is one worry that I think overrides all the others -- soil erosion. But I think you have to conclude that we could double the population here in our region, up to 400 or 500 million, and with prudent control of depletable resources and control of erosion, maintain the carrying capacity in terms of food production. To double it again and reach China's current population might put some real strains on the basic systems, although China has a comparable arable land base. Please do not quote me as recommending this as national population policy. I am attempting to consider carrying capacity as a variable, over which we have some control in at least some categories.

But now let us consider the third possible cause of a decrease in carrying capacity, a variable over which we might not have much control: climatic variation. From Bryson we know that climate varies, even to some inhospitable extremes in previously hospitable areas, without the presence of humans. We know that these variations have periodicity and that climate variation is driven by physical forces. But we also know now, with some degree of confidence, that human manipulation of the environment can modify climate or, of even greater concern, could help flip the ambient climate from one modality to another.

Let me explain. Assume that the earth is in a natural warming trend and that we increase carbon dioxide in the atmosphere, which does *more* than gradually accelerate the warming trend, resulting in a gradual increase in the size of deserts. The climate shifts into a different modality that greatly favors deserts, say, in the North American heartland. One of Bryson's main intellectual contributions is on this very point: the conceptualization of rapid shifts in climate modalities given a certain threshhold reached by the driving forces. He has

more often talked about the other end of the scale, that is, from a relatively warm and hospitable situation to a glacial-type climate -- not glaciation looming overnight, rather a glacial climate. Such shifts can be devastating to biological structures.

I said that we *might not* have control over climatic shifts. Obviously, we might bring ourselves to restrain activities that would cause or accelerate such a shift. But if we knew that we were sliding into a little ice age, such as the one that appeared between 1200 and 1300 A.D., whether a natural fluctuation or human-precipitated, would we then try to bring the forces of technology together to reverse that natural trend? Would we try to manage climate on a global scale? Possibly.

We might try climate modification on the proposed scale of Star Wars. We might try to figure out a way to melt the growing ice caps by shifting the albedo -- the reflecting capacity of the system -- or the insolation capacity at the surface of the earth, particularly if we understood that glaciers were "seeded" in certain locations susceptible to control techniques. Or we might try to redirect ocean currents or rivers to modify continental climates. We might even try to *increase* the carbon dioxide in the atmosphere, using it as a kind of nutrient to grow a hospitable climate, the way we enhance soil with nitrogen fertilizer for a more hospitable plant bed. We might even, 100 years hence, pat ourselves on the back for postponing a glacial climate by having burned the fossil fuels.

At this point, I would like to return, rather abruptly, to metaphor. We have all had this experience. You are in a big, modern airport -- let's say Denver's Stapleton Field -- and have 10 minutes to make a transfer between planes. Fortunately, they have one of those horizontal, moving passenger belts. You step on the belt and you go sailing along. But the belt is not fast enough, and so you start running. You gain that sense of momentum, almost as if you were defying both inertia and gravity, and you have every confidence of getting down to Gate 117 on time.

I had a nightmare recently. I jumped on the end of the moving belt before realizing that it was running in the opposite direction. I was somehow unable to turn around and ride out the mistake, but neither could I get to the far end, because as I ran faster, the belt accelerated. I started losing ground because I had a heavy piece of carry-on luggage, and I kept bumping into people coming at me from the opposite direction. People got angry at me. I felt the urge to fight back. I started swinging with my carry-on luggage. The luggage broke open and things spilled out behind me . . . and the belt carried them away.

My dream faded at that point. And I was awake, absolutely relieved to have gotten out of that one! Dreams are that way. You always wake up at the right moment.

I could pursue my metaphoric nightmare further, but perhaps it is not necessary. But we ought to deal with the implied issues, and I do think I need to return to Alice's dream and the original question. Remember what I asked? "If we are all Alice, expecting to get somewhere after working very hard at it, who then is the Red Queen?" Consider the possibility that *we* are *both* Alice and the Red Queen. Just before they sat down under the tree to rest, Alice was clearly the one that was out of breath, thirsting for a big drink of cool water. But it was the Red Queen, was it not, who suggested that they both rest for awhile? That they take it easy? That they think it over?

I said earlier that the words "economic development" have dominated the public mood in the 20th century. I want to leave the impression that development is reasonable and desirable. This is not a lecture about nightmares. There is much good to come of development. What is at issue is the *mode* of development.

Now, however, we need to figure out a way to give the same intense attention to carrying capacity that we have to development. That is what we need to develop in the 21st century: a deep and careful understanding of carrying capacity. But we need to do more than understand it in an ecological sense, though that is where we start. If we have the cleverness to develop resources, we also have the cleverness to match development to carrying capacity in a pragmatic way.

One of the key concepts in resource economics is to set a reasonable rate of depreciation of the future value of a resource. It is quite a simple concept. If you feel you can make a profit exploiting a resource, you can reinvest that profit and get an additional return from the reinvestment. You will set a high rate of depreciation if the reinvestment is attractive. You will also accelerate the rate of depletion of a resource if you feel that a more attractive substitute will soon come on the market because the economic opportunity will be lost in the resource you own if a cheaper substitute comes along. On the other hand, you will postpone exploitation if you feel the resource will be much more valuable in the future. You will leave it in the ground and let it appreciate. While the judgment on how fast to exploit a resource is just that -- a judgment -- it is a rational way to value the present and future value of a resource. We make mistakes in the rates that are set, but that is not a reason to reject the concept.

The problem is that we apply the concept *narrowly*. If we apply it to a strippable coal bed, we try to focus our decision on the present and future value of coal, not on the value of the land surface, or aquifers, or air quality. We ignore such costs in the contract or attempt to pass them on to "consumers" or to future generations -- real though the costs are. We ignore the costs unless some intervening institutions consider them for us. In passing on the costs, we lose sight of the larger issue, which is sustainable carrying capacity.

Refining this methodology to depreciate the future value of a resource has almost become a way of life for people who make economic decisions about resources and about the environment. We routinely depreciate the future value of petroleum stocks, copper, even agricultural lands, and a host of other things, and that process of devaluation does tend to become a major impetus for accelerated exploitation. Not knowing what the future may bring in the way of risks for our "investments," we take the money and run.

So here is my pitch for this evening. Here then is what I suggest for further conversation as we have a drink of cool water in the shade of a bur oak tree on a warm summer day: *We need to reorder our decisionmaking so that we consider the future value of carrying capacity, not just the future value of single resources*. We need to estimate the rate at which we are depreciating carrying capacity in literal, economic terms. We need to do it in the computer -- before we do it on the earth's face.

As I have indicated, the notion of taking an analytical look at the future value of resources is not foreign to our dominant patterns of economic thinking. There are the methodological problems of expanded scale and concept, but they are not overwhelming obstacles. Economists have also given much thought to risk assessment and risk management, but again there is a tendency to think of single resources or single threats. We could estimate the parameters of carrying capacity that constitute risk and set some boundary conditions for development by working the costs of high risks into the original decisions. If you are worried about more government, consider what environmental decay approaching catastrophe will bring. Imagine Egypt's problems if there is not enough water in the Nile to go around. We can integrate such concepts and conditions into economic decisionmaking through management and regulations where the market cannot accept them.

I have been fussing for years about how to foster a mood of detente between the economists and the ecologists. They seldom talk to each other in a friendly way, let alone an analytical way. They often shout at each other. But the economists understand development with increasing sophistication, and the ecologists understand carrying capacity with increasing sophistication. I do not think they are so far apart if they would only put their minds to the issues and apply the methodologies that exist just beyond the horizon. The possibility for new approaches is certainly worth the effort.

Let me leave you with just one such concept. I propose that we develop a "GNCC": a gross national carrying capacity. This would be an index of the various specific indicators of where it makes sense to to expand carrying capacity but also where there is a measured loss of carrying capacity. It should not be any more difficult to develop than the gross national product, and it could be very useful if it served as a balance to that well-known index.

If you find the concept of GNCC a little fuzzy, then consider the idea of a set of "leading environmental indicators."

Environmental Criteria and World Bank Loans

Robert Goodland

Economics and Sustainability

My talk tonight is an informal one, and it represents a personal view. I emphasize that it may not represent the official position of the World Bank.

Let us begin with at least one definition of sustainability. Sustainability optimizes benefits to the present generation -- nothing new there -- without jeopardizing the likely potential for similar benefits in the future. A *lot* new there. This definition assumes a level of well-being that can be perpetuated for many human generations. The time factor in this definition is of the essence. It implies that there must be a societial and global transition away from economic growth based on depletion of nonrenewable resources -- oil, for example -- and towards renewables. Human well-being is dependent on three factors. First, efficiency, and this is already routinely factored into many societal decisions. Second, equality, meaning the equitable distribution of benefits and opportunities within society or, put another way, the distance between the rich and the poor. This is scarcely factored in at all. You in the United States are lucky in that the gap between the rich and poor is relatively narrow. That is the exception, not the rule, in the world as a whole. And, finally, the third factor determinant of human well-being concerns noneconomic values: our spiritual values, ethics, aesthetics, and even our self-esteem. These are not acknowledged by many decisionmakers and scarcely acknowledged in orthodox or conventional economic analysis. But I propose to you that they should be. Development should aim to optimize the relationship of these three factors because clearly some tradeoffs are inevitible among them.

Let us return again to the time element in our definition of sustainability. In the jargon of the trade, the term for this is "intergenerational equity." Although it is impossible to predict with any precision the likely interests of future generations, it seems prudent to me to assume that their need for natural resources such as soil, air, water, forests, fisheries, biodiversity, energy, and minerals will not be markedly less than ours. Therefore, sustainable development implies using renewable resources in a manner that does not degrade them. It implies that renewables ought to be harvested on a sustained-yield basis and not mined to near-extinction. Whales, tropical forests, and coral reefs are examples of renewables that are often mined rather than harvested sustainably.

High discount rates, commonly 10% and more, discourage long-term investments and promote short-term investments. It is difficult to invest in forestry, for example, in developing countries. They would much prefer to have the World Bank invest in a steel mill or in projects to improve rice production -- investments that take less than a year to come to fruition -- rather than in a forestry project that may take 15 years to show a profit. One example of the fundamental importance of the discount rate is the whaling industry. If a whaler can make a 15% annual profit by exterminating the resource -- the whales -- over perhaps 10 years and can then invest the profits in a different sector, semiconductors in Taiwan for example, then what economic incentive is there to make a 10% profit by harvesting whales sustainably? The answer is: none. This is only one example of the dangerous direction in which orthodox economics can and indeed is leading us.

Sustainable development implies using nonrenewable, exhaustable mineral reserves in a manner that does not unnecessarily preclude their use by future generations. For example, it will be easier in the future to use today's scrap metal if it is recycled rather than dumped in a haphazard manner. Sustainable development also implies depleting nonrenewable resources at a slow enough rate to ensure a high probability of an orderly social transition to renewable

sources such as solar, biomass, wind, and hydro, when nonrenewable energy becomes substantially more costly. This transition from exhaustables, particularly oil, toward renewables is inevitible. That is not the question. The question is whether we as a society, now that we have predicted it, can make the transition in an orderly fashion. If we do nothing, or not enough, and allow the transition to be sudden and let current trends dictate the timing of that break, it will be a very painful shift for us. The choice is ours, but we do not routinely face up to it today.

Agricultural sustainability implies the permanent maintenance of biological productivity on-site, with the cost of such imported inputs as diesel fuel, biocides, and fertilizers not exceeding the commercial value of the site's production. This offends the standard economic approach by saying that these rich soils here in Wisconsin, for example, ought not be mined, which I understand is often the case.

These sustainability factors are not new to you. As individuals, the more concerned and thoughtful among us already drive smaller cars or walk, recycle waste, and behave thriftily to a certain extent. As a society, though, we allow ourselves and our globe to be operated according to a system of frontier economics that came into being when the world had relatively few people, when resources were scarcely tapped, when air and water were clean, and land and forests abundant. This idyllic era has long since vanished. But the economic orthodoxy has yet to be modernized to reflect today's densely populated world. Possibly the single most influential change towards sustainability that can occur is the revamping of neoclassical economics to accommodate environmental concerns, particularly to include ethics, nonhuman values, sustainability, and the internalization of ("external") costs.

In most introductory economics texts, economics is still viewed as an isolated circular flow of production and consumption. Capital and labor, they claim, can substitute for resource inputs, but this conceptualization is clearly limited. This is like an ecologist describing an animal's circulatory system in detail while omitting the fact that the animal also has a digestive tract and respiratory tract.

Economists have to realize that the economic process of production and consumption also includes a digestive tract of sorts and that it is a "one-way tract," and that this one way is irreversible: It takes in resources and excretes waste. Hence it is irrevocably and tightly linked to the greater ecosystem. The economic subsystem depends on the overall ecosystem, first, as a source of raw materials and, second, as a sink for its wastes. Both the sources and sinks are finite. Therefore, the main variable in this whole system -- which is to say the overall ecosystem that surrounds the subsystem of economics -- is the throughput between the source and the sink. Therefore, the dependent role of the economic subsystem within the ecosystem raises the question of how big the economic subsystem should be in physical dimensions relative to the overall ecosystem. This issue is hardly even recognized, much less addressed, in economics today. Herman Daly is the sole leader in this topic.

Now that the source and sink functions of the ecosystem are overstressed, the size of the throughput has begun to matter. This calls into question the concept of growth economics, the goal of maximization of gross national product, and the relationship of growth as now defined to welfare, equity, and the impossibility of generalizing western standards to the entire world. In the United States alone, 6% of the world's people use 30% of the world's nonrenewable resources. This is clearly an impossible standard for the other 94% of the world's population to hope to attain. You only have to imagine one billion Chinese with one or two automobiles. Therefore, we need to define economics and economic development in a way that is generalizable. Back, then, to this concept of throughput. Economic development must be redefined, less in terms of expanding GNP and more in terms of controlling population, balancing the source and the sink functions with population, and certainly more in terms of limiting inequality.

Large parts of our planet, curious though it may seem in idyllic Madison, have already exceeded their carrying capacity. Those of you who have traveled to the developing countries, the Third World, are well aware of this. But what is the evidence for this assertion that we have exceeded the carrying capacity over major portions of the globe?

The first bit of evidence is that humanity is able to support itself -- and none too well at that when you consider that several thousand starve to death every day -- only by consuming inherited capital. If you inherit some capital from your parents, you can live off it like a lord for a couple of years, but it is not sustainable. Not only have our inherited stocks of oil and minerals been squandered, but the earth's topsoil, groundwater, and biodiversity also are being depleted.

The second bit of evidence that we have exceeded our carrying capacity came to our attention just this month. If you follow the newspapers, you know about the 3,186 tons of New York garbage that has been barged 6,000 miles, refused by five states and three nations -- Mexico, Belize, and the Bahamas -- for over four months, and has yet to find anyone who will allow it to be dumped nearby. This is an indication that there cannot be too much unused space. Again this month in the newspaper, we read about the Nuclear Regulatory Commission's failure to rent a long-term dump for radioactivity waste despite the multimillion-dollar annual bribes it has offered to many small townships.

In just the 60 minutes that I expect this talk to last, 9,000 babies at about 150 births per minute will have been born. This audience multiplied one hundredfold. If demographic inertia, the greenhouse effect, acid rain, and loss of tropical forests are included, then the claim that much of the world already has overshot its carrying capacity becomes ominously real. This is the evidence in the case for a shift from growth economics to steady-state or sustainable economics, from quantity to quality.

Let us consider now the ethical side of these economic concerns. Economists speak of the "satisfaction of relative wants," but just as it is impossible for everyone's income to be above average, so it is impossible for everyone's relative incomes to increase as a result of that growth. This is not widely understood. In rich countries, welfare increases with relative, not absolute, income. All of you in this room, I presume, are above a certain basic level of sufficiency and so will feel rich only if you are wealthier than the Joneses down the road, not if your relative economic status is the same.

Thus, aggregate growth above sufficiency leads to self-canceling effects on welfare. And since aggregate growth does not improve welfare, it is undesirable even though it is possible. It is undesirable because it augments throughput in the economic subsystem, hence, it further strains the sources and sinks of the overall ecosystem. Opting for throughput on this scale is a social decision rather than an individual economic decision. The race to take over wildlands and wild habitats, the rate of drawdown of geological capital as in the case of oil -- these are decisions concerning sustainability, intergenerational equity, and justice. Hence, we face an immediate need to integrate ethical criteria into economics and into society's decisionmaking in general. Let me further add that similarly important ethical issues concerning nonhuman species must be considered, and there should be no illusion that this will be easy.

The Environmental Context

As we turn now to some environmental aspects of the sustainability concept, let's back off a minute and look to history -- though I refuse to lecture on environmental history to a state that nurtured both Aldo Leopold and John Muir. As you know, the modern environmental movement began in large part as a reaction to serious pollution problems. Now with the blinding clarity

of hindsight we see that this is a pity because pollution, although certainly a legitimate environmental concern, is a rather atypical one. It fits into that group of circumstances that are, to a degree, reversible. The more important environmental concerns are the irreversible ones. This distinction between reversible environmental effects and irreversible environmental effects is, I believe, of fundamental importance, and I commend it to you.

Pollution, then is an example of a reversible environmental effect. In a notorious "pea soup" smog in London on the fourth of December 1952, 4,900 extra people died in just one night. That led, two years later, in 1956, to the passage of the Clean Air Act, and now London, though perhaps not as clean as Madison, no longer has people dying of bronchitis every night.

What is the lesson of this and other extreme examples of polluted environments that have managed to recover at least partially? The lesson to me is that if you are foolish enough to run your planet or your backyard in that way, and if you have enough money to throw at such problems, you can reverse them. I am sorry that it took 4,900 deaths in the case of the London pea soup smog before the political will was mustered to pass a clean air act. But that is apparently what it takes for us to realize that it is at least possible to reverse circumstances that should never have come about in the first place. Now we have a whole body of literature chock full of adroit economic legerdemain to control pollution via economic incentives. By and large, the economics of it have been figured out.

To me, the much more interesting cases concerning the environment are those that involve irreversible effects: the carbon dioxide greenhouse effect, the depletion of the ozone layer, the contamination of groundwater, the loss of topsoil, and so on. Again, the loss of topsoil is of primary importance to you here in Wisconsin, for civilization may well be able to survive the exhaustion of oil reserves but the continuing loss of topsoil will certainly kill civilization. Also in this irreversible category I would include extinction of species and the attendant problems of tropical deforestation and the loss of genetic diversity.

A dental analogy illuminates these long-term, irreversible effects. You may hate the dentist, but when the pain in your tooth has crossed a certain threshold you will voluntarily take yourself to the dentist's chair to get treatment. Pollution is like that. Again, 4,900 unnecessary deaths is not indicative of a well-run enterprise, but if you have enough money you can clean the air -- that is to say, if you have enough money to pay the dentist. But irreversible effects are just that: irreversible. No amount of money can bring back extinguished species. And, of course, the tropical countries, whose forests constitute 7% of the land area of this globe but contain an enormous 50% of the world's species, are the poorest countries. They cannot afford the folly of environmental damage, whether it is pollution or extinction, because they simply do not have the money to solve the problem.

You may well ask what tropical forest deforestation and biodiversity have to do with Madison, Wisconsin? They have much to do with it. First, the United States exerts an enormous demand for tropical products, particularly tropical hardwoods and veneers, but also rubber, cocoa, and beef, which I'll come back to in a minute. Also, the United States owns a certain amount of tropical moist forest in Puerto Rico and Hawaii.

Of course, if tropical deforestation brought nothing but lasting benefits to the world my argument would be untenable. Even as it is, the world is full of people saying, in effect, that one cannot make an omelet without cracking eggs; in other words, we lose our forests, but a lot of jobs are created and a lot of people recieve major benefits. This, however, is not the case. Destruction of the tropical moist forest brings ephemeral benefits for a very few people and no lasting benefits whatsoever.

A prime example of this has been called the "hamburger connection." The situation is described by Chris Uhl. His argument -- and I think that it is entirely sound -- is this: If cattle gain about 50 kilograms per hectare per year and are slaughtered after eight years -- and these are reliable figures -- and half the weight is nonmeat such as skin and bones, then each cow produces 200 kilograms, or enough meat for 1,600 hamburgers. Assuming one hectare of tropical moist forest weighs about 800 tons -- again a very average, reliable figure -- this means that half a ton of forest is converted into one hamburger. Put another way, 10,000 square meters per hectare of forest divided by 1,600 means that one hamburger is derived from 6.25 square meters of forest. The question is quite obvious: Is one hamburger worth the permanent and irreversible loss of all this joy and diversity? Even if the issue is argued on a dollar basis, it is not worth it. After 10 years most tropical pastures are abandoned due to depleted soils, declining fertility, increasing weeds, and compaction as a result of overgrazing. This translates into a pittance of three U.S. dollars income per hectare per year.

The manifold values of tropical wet forests are extremely well outlined in Paul Ehrlich's book Extinction. One value that I learned of in preparing this talk is that some 97% to 99% of potential crop and human disease vectors are controlled by intact ecosystems. Another aspect of tropical deforestation is that it is very *urgent*. We have some 10 to 30 years left, depending on locality. In Haiti and El Salvador, for example, we have no time left; it is already too late. There it is wall-to- wall cattle pasture, with practically no intact tropical moist forest. All of the biodiversity in those two countries is irreversibly lost. There are other countries in more or less the same state, and many others rapidly propelling themselves toward that state. This means that if our generation, the generation sitting in this room, does not conserve at least representative samples of this world's biodiversity, it will not be there for our children to conserve.

Moreover, many species in the tropical forests may already be "living dead." The term "living dead," coined by Daniel Janzen, means, for example, that although a huge tree may be alive and producing flowers and fruit every year, it is no longer breeding. The pollinator may be missing, the seeds might not be viable when they fall beneath the tree, or the tree may belong to a nonviable population. Many such extant species may actually be "living dead." So time, sadly, is not on our side.

The major needs in this respect include the selection of wildland samples to be preserved, the design of wildland conservation tracts, and the rehabilitation of degraded habitat. We need, too, to check the tropical lumber trade as well as the processes that force peasants off fertile land and into the forests and onto the slopes. In general, the people who cut the forests are not the ones to blame; they are simply trying to survive. I would like to end this section with a quotation from Professor Ed Wilson of Harvard, who wrote, "The worst thing that can happen . . . will happen in the 1980s, is not energy depletion, not economic collapse, or limited nuclear war, or conquest by a totalitarian government. As terrible as these catastrophes would be for us, they can be repaired within a few generations. The one process ongoing in the 1980s that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. This is the folly our descendants are least likely to forgive us."

Working Toward a Sustainable Society

So much for the theory then. What are you -- we -- going to do about all this? As Edmund Burke said, "The only thing necessary for the triumph of evil is for good men to do nothing." And also as one of the founders of the World Bank, Lord Maynard Keynes, said, "We will do the rational thing, but only after exploring all other alternatives."

Again, I hesitate to discuss environmental activism in the state where Aldo Leopold and John Muir once operated, but I will. If you are politically inclined, and I sincerely hope some of you are or will be, then certainly go this route. It can be very effective. We need not question the motives of congressmen who are exercised about the disappearance of tropical forests; the fact that they *are* exercised is enough, and they pass bills in your Congress. Regardless of the source of the pressure on them, they put pressure on the U.S. Treasury, the U.S. Treasury puts pressure on the World Bank, and the World Bank and other multilateral development agencies try then to finance the conservation of biodiversity. That is the political process, and of course we could have many lectures just on that theme. I hope some of you will move in that direction.

The other direction is economic, and I want to say even less about that. Again, Herman Daly and a very few others are leaders in the movement towards steady-state economics. Any of you who are economically inclined can reap enormous benefits for the rest of us if you are capable of learning the economists' language and straightening them out.

I would like to discuss very briefly a number of the nongovernmental organizations, moving mainly from the more "establishment" to the "less so." If it is your metier to drink cocktails with the chief executive officer of a multinational corporation, then that is what you should do. You should join the organizations at the top of the list -- Resources for the Future, the World Resources Institute, the Conservation Foundation -- all of which are eminently respectable and squeaky clean and which maintain excellent relationships with multinationals. I do not say this in a deprecating manner at all. Personally, I do not feel very comfortable drinking cocktails with chief executive officers of multinationals, but if you do, that is what you ought to do. They have a lot of money and it makes them feel good, look good, and be good if they give you a lot to invest in the conservation of biodiversity.

Coming now to the middle of the list, there are grassroots nongovernmental organizations that survive on thousands of modest contributions, and these are even more important. If that is where you feel at home then by all means join them, raise funds for them, and activate them in whatever way you can.

Coming now towards the end of the list, if you are foolish enough to interpose a fragile human body, particularly your own, between a harpoon and a whale, then you know which organizations to join. Or if you are courageous enough to interpose the same fragile body -- assuming the harpoon did not get you -- between an encased concrete block of nuclear wastes being dumped at sea, you again know what groups to join. I do not for a moment endorse violent tactics, but they do have one advantage: They make the people who are not violent look more moderate.

In short, you should really choose the route that you personally feel most comfortable with, whether it is politics, economics, or environmental activism. Build on your strengths. I think it is a weakness of my profession, ecology, that we do not bother to learn the jargon of the economists and the decisionmakers. And I urge those of you who have this capability to do so. By all means study, publicize, lobby, write letters, and demonstrate. I have already urged you not resort to violence. Violence clearly breeds violence, and violence breeds totalitarianism. I remind you of Dr. Diane Fossey, who was macheted to death on Christmas 1984 in Uganda while protecting our nearest nonhuman relation, *Gorilla gorilla beringei*, of which there are only 252 specimens left. Again, on the 10th of July in 1985, a civilized western democracy that shall remain nameless officially sanctioned the bombing, which is an act of war, of Greenpeace's vessel, the Rainbow Warrior, in Auckland Harbor, murdering one of the occupants, Fernando Pereira.

In addition to joining some of these groups you may want to improve the economic development process more directly, and you need not be an economist for this. I will give you one example that I am close to, the World Bank. The World Bank is owned by 151 member countries, which

means that practically all of the world's biodiversity is contained therein. We lend more than $17 billion a year for various economic development projects, but this is a small sum compared to its total impact, because this $17 billion is leveraged at least threefold by the borrower. We rarely invest in more than 25% of any one project. This means we never have any white elephants. A government must be very strongly committed to any project if it has to put up 75% and we put up only 25%. And then it is leveraged again, possibly by one order of magnitude, because the government is influenced by our economic analysis. And you, the United States citizens, contribute nearly 20% to the World Bank, more than any other nation. Therefore, the World Bank can be potent agent for the achievement of your goals, that is, for the conservation of biodiversity.

The World Bank's Strategy for Sustainable Development

As Saul Alinsky advised, the best way to change an institution is to force it to abide by its own rules. The World Bank's wildland policy is already in place. Conservation of biodiversity has been incorporated into the bank's policy. All of this has been officially promulgated, and every person in the World Bank has a copy and is supposed to use it in day-to-day work. We have also instituted a policy on tribal peoples, forest dwellers, and other unacculturated ethnic minorities, and of course they are enormous agents for the good and for the conservation of biodiversity. They know how to live within the tropical wet forest. We do not.

So far the World Bank has financed biodiversity preservation in about 26 countries and 40 projects worldwide. This adds up to a protected area of 60,000 square kilometers, larger than the entire country of Costa Rica. The largest biodiversity preservation project is in the Amazonian part of Brazil, in the state of Rondonia, where we are financing the protection of about 19,000 square kilometers, an area larger than El Salvador. In this protected area we are also financing the use of Landsat, which overflies the area every 18 days. We are financing helicopters and hovercrafts so that when the tapes from the satellite are interpreted, any discrepancies in land use from the previous months can be investigated. If it is a normal forest fire, not much can be done about it. If it is an illegal logging operation or settlement, an armed battlion of forest police -- also financed by the World Bank -- is sent in to resettle the people or to confiscate the expensive machinery of the logging corporation. This is having an effect. The security measures have been in place for about three years, and already invasions of the protected areas, whether they are Indian reserves or national parks or biological reserves (or ecological stations, as they are called in Brazil), have declined. These areas are now increasingly left alone except for research.

To change an institution by making it abide by its own rules you must first know the rules. And so I would like now to outline briefly this new wildland policy. The general policy of the World Bank is simple: The bank shall not hereafter finance the destruction of wildlands. Rather, we want to finance their conservation, and this translates into six specific policy elements.

The first is that we normally decline to finance conversion of "wildlands of special concern." The definition of "wildlands of special concern" takes up pages of the report, but essentially it describes two categories. One includes those lands, such as national parks and already-protected areas, which everyone agrees should remain protected, and also those areas that the country and the scientific community would like to see protected but have not quite gotten around to doing so yet. The other category of "wildlands of special concern" is rather fuzzier. These are the lands for which there are no active plans to secure official protected status but in which there is reason to believe there are elements of special biological interest. For whatever reason, there is cause not to chop them down. This, then, is the first policy element.

Now you may query the weasel word in the statement that the World Bank "normally" declines to finance conversion of wildlands. This provides leverage. For example, you may have a very large national park that is mainly a desert in country X, and the Ministry of Electricity wants to flood 1% of this desert national park. The tradeoff may be that, yes, the reservoir can be built, flooding 1% of this desert national park, but the park gets perhaps $1 million a year to operate and so is able to elevate itself from the status of a paper park to a viable conservation entity. It might also acquire a 1% of equivalent land in its northeast corner in compensation for the 1% lost. This sort of *quid pro quo* can really help. That, then, is what the word "normally" means.

The second policy element states essentially that the project should be sited on already-converted land, not intact habitat.

The third policy element is that deviations from these policies have to be explicitly justified. You in the United States have democratic mechanisms of town meetings, hearings, publication of plans, and posting even of building permits. This is very rare in developing countries. Most decisions are made behind closed doors in one ministry. This third policy element specifically seeks to avoid that closed-door decisionmaking. This does not mean that decisionmaking immediately follows the town meeting route that you are lucky enough to have, but it does mean that the procedure has to be more open than in the past and that the options must be aired outside the implementing ministry and must include the ministry of the environment, academia, and nongovernmental organizations at the very least.

The fourth policy element states that when the conversion of wildlands can be explicitly justified, then less-valuable wildlands should be converted before more-valuable ones. If nothing else, this will keep our ecological colleagues well employed because the relative ranking of wildlands requires several years of on-site biotic inventory. In the process, we will improve our knowledge of biodiversity. It is an intrinsic fact of life in the tropics that the moment you send any good taxonomist into any intact ecosystem, lots of rare species will come to light. The ecologists may find that even the less-valuable areas are so valuable that development should take place elsewhere.

The fifth policy element again applies when wildlands are not of special concern. This is the real crux of the policy. It states that such wildland loss must be compensated for by financing the preservation of a similar wildland elsewhere. Again this means a lot of employment for our ecological friends. They have to choose a compensatory tract, and this compensatory tract has to be similar both in area -- if your reservoir or your oil palm plantation is going to be a thousand square kilometers then you have to set aside a comparable thousand-square-kilometer tract -- and in richness of biodiversity. It will require much careful study to make that case. This fifth policy element, I repeat, is the real crux of the policy.

The sixth and final policy element asserts that we should now preserve wildlands for their environmental service value alone. That is to say, for example, that we can preserve a forest simply for its environmental service value. A good example of this took place on the northern Indonesian island of Sullawesi. The World Bank financed a small irrigated rice project of less than 200 square kilometers, and water for this project came from a watershed that has been given national park status as a result. And this was at a very modest cost; about 1.5% of total project costs -- about 1.1 million dollars -- was needed to secure protection for this entire watershed, none of which was to be affected by the rice scheme itself. The rice project did not require the cutting down of any forest, and it has resulted in a new national park. That park became the site of the world's largest-ever scientific expedition. It was called Operation Wallace, and it occupied hundreds of scientists over three years. They discovered many new species, and because it takes years to discover what one has in a collection, many more species will be discovered in the years to come.

There you have the opportunities. I have covered much territory. It is up to you to maintain constant vigilance and to work with the ministries of the environment and wildlife departments in developing countries, with their implementive ministries such as agriculture or electricity, and with development finance agencies as well. I do not claim for a minute that this process will be easy. In fact I know personally that it is not. With effort, however, it is possible and it is certainly better than the alternative of accelerating extinctions.

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Decline of the World's Tropical Forests

James Nations.

Tonight I want to try to convince you that a positive future for tropical forests is possible and that it is crucial if we expect to achieve sustainable development for the human societies on our planet. I will be focusing for several reasons on the tropical forests of Latin America. First, Latin America contains the largest block of tropical forest that still exists in the world. Second, the tropical forests of Latin America are the closest to us and have the most impact on us as citizens of the United States. And, third, that is the area I work in.

One hundred years from now your grandchildren may look back on the second half of the 20th century, the decades in which you and I are now living, and refer to it as "the time of the great dying." They will be referring to this brief period of time when much of the earth's biological diversity is being decimated in the name of survival and progress and profits.

Paleontologists speak of the end of the dinosaur age as a period of massive extinctions, but during that period, despite the assistance of asteroids and dust clouds, the planet lost an average of one species every thousand years. Today, many biologists think that human activities are eradicating plant and animal species at the rate of at least one per day, and these scientists predict that by the end of the century the rate may reach 10,000 species per year, or more than one per hour (Ehrlich and Ehrlich 1981; Myers 1979; Wilson 1984, p. 13). Those figures are only estimates. We do not know exactly how many plant and animal species are being eradicated because we do not know how many species there are in the first place. Unfortunately, some researchers have used that uncertainty to dismiss these predictions of large-scale extinction.

Bear in mind, however, that almost every scientist doing research on species extinction will guarantee that we have a serious problem. The number of naysayers can be counted on one hand. The majority of biologists will tell you that we are in the midst of a period of species extinction comparable to the mass extinction episodes that we find in the geologic past. The difference is that today the high rate of extinction is due not to dust clouds or changes in climate but to human activities. The biologists will also tell you that most of the species that we are eradicating are insects, primarily beetles and butterflies, and that most of them are restricted to small territories. In some cases, they may be restricted even to a single tree. But those insects are joined in extinction by a variety of birds, mammals, and reptiles, and by hundreds of species of plants.

The chief cause of this eradication of species can be defined in one phrase: loss of habitat. That phrase, in turn, can be narrowed down to one word: deforestation. And deforestation is primarily a problem of the world's tropical rain forests -- the forests that we normally think of as "jungles." The reason that tropical forest destruction is so severe is simple: They are the world's largest depository of plant and animal species. Tropical forests are home to more than half of all the species on earth, and that may be a conservative estimate. Terry Irwin, a scientist at the Smithsonian Institution, is carrying out research in Peru and Panama that indicates that there may be as many as 30 million species of insects, most of which live in the canopy of tropical rain forests. The ironic thing about this destruction is that we know so little about what we are destroying. The vast majority of species in the tropics have never been seen by scientists, much less examined for their potential impact on the sustainability of human societies.

Don't let anyone try to tell you that tropical forests do not matter, or that they have not provided important products to us in the past, or that we have already taken all the species that we need from them. If you have ever eaten rice or chocolate, a banana or a pineapple or

an avocado, you have eaten crops that originated in the tropical forests. The rain forests that still exist protect the original genetic material, the germ plasm, for those crops, and that represents the potential for crop improvement over time. Plant breeders use that wild germ plasm to alter these crops for human benefit -- to make them more productive or to make them resistant to disease.

Dr. Hugh Iltis, director of the herbarium here at the University of Wisconsin-Madison, helped discover a wild relative of corn that turned out to be resistant to seven major plant diseases (Iltis et al. 1979). It is estimated that the benefits of that discovery alone, worldwide, may eventually be measured in billions of dollars per year. In fact, the value of all types of wild germ plasm to U.S. agriculture is said to total $700 million every year (OTA 1984).

Consider just a few of the crops that originated in tropical forests: rice, corn, sweet potatoes, manioc, sugar cane, oranges, papaya, mangos, peanuts, cinnamon, cloves, coffee. Without tropical rain forests the Swiss would have no chocolate, the French would have no vanilla, and the Italians would have no tomato sauce. All of those crops originated in tropical forests -- in fact, in the tropical forests of Latin America. If you eat chocolate, remember that cacao beans originally came from the Amazon rain forest. Its wild precursor still grows there. Plant breeders can use those wild strains of cacao to improve the cultivated variety and protect it from plant diseases. Maybe you drink hot tea or iced tea. Tea originated in the rain forests of Southeast Asia. As Mark Plotkin of the World Wildlife Fund likes to point out (personal communication, 1987), each and every one of us is eating tropical forests for breakfast.

We need tropical forests, then, to sustain the productivity of modern agriculture. And we need tropical forests to develop new crops that will sustain the human food supply. Don't let anyone tell you that new tropical forest plants do not get introduced. A century ago, bananas were considered an exotic food in the western world. When they were first introduced in the United States, they came individually wrapped and cost two dollars each. Twenty years ago, the average supermarket in the United States carried about 65 kinds of fruits and vegetables. Today, many of them have at least 140 species of fruits and vegetables, and some of them have 250. There is a supermarket in Florida that carries 400 different fruits and vegetables during the course of the agricultural year. As the home of at least half of all the species on earth, tropical forests are the primary source of new species that are of use to human beings.

I have not even mentioned tropical forests as a source of new drugs and medicines. When you walk into your local pharmacy there is a one-in-four chance that the substance the pharmacist hands you contains active principals derived from plants, most likely from plants of the tropical forest. Seventy percent of the plants that are known to have anti-cancer properties come from tropical forests, and most of those were introduced to us by traditional peoples who live in tropical forests. According to the World Health Organization, almost 80% of the world's women, men, and children rely on traditional medicinal plants for their personal health care (Farnsworth et al. 1980).

So when we say that during the next 25 years human activities will destroy thousands of species of plants and animals in the world's tropical forests, how many new medicines and how many new food crops, how many natural insecticides and how many oil-producing trees will we be destroying? The answer is -- we don't know. All we do know is that tropical forests and the species that live in them are being effectively eradicated in many of the world's tropical countries. The best estimates now are that human activities are eliminating at least 24,000 square miles and maybe as many as 37,000 square miles of tropical forest every year (Melillo et al. 1985, pp. 37-40).

That is not to say that the entire stock of tropical forests will be wiped out during your lifetime. The rain forests of some countries appear to be safe well into the next century. In Africa, for example, the rain forests in Zaire and Gabon should survive for many decades. In South America, the rain forests of Guyana, Suriname, French Guiana, and of much of the western Brazilian Amazon should stand for at least another 30 to 50 years, years that we can use to work toward their wise use and conservation.

I want to emphasize, however, that while the eradication of our planet's biological diversity is the most threatening repercussion of tropical deforestation, it is only one of the repercussions. Tropical deforestation can affect the sustainability of human societies in tropical areas and may affect the sustainability of human societies on our planet.

On a local level, for example, tropical forest destruction increases the level and frequency of flooding and results in accelerated soil erosion and severe siltation of lakes and rivers. The situation is this: Normally, uncut tropical forests act like a sponge. They absorb and then recycle the water that falls on them in the form of rain. A cloudburst that drops an inch of rain in half an hour on a tropical forest will have at least half of that rain intercepted by the forest canopy. The forest soaks it up and then releases it gradually into streams and rivers for the benefit of human populations and wildlife that live downstream. But if that forest is cleared, the rain comes in, hits the soil, runs down the slope, and carries the topsoil with it. Flooding occurs because there is no vegetation to absorb the rain, and soil erodes because the increased runoff carries the soil down the slope. Downstream, that lost topsoil, as silt, can damage crops and smother entire fish populations. The repercussions for people who subsist on fishing or farming are obvious.

On a regional level, that same siltation can cut the lifespan of hydroelectric dams in half by silting in the reservoirs that provide the water used to generate electricity. In Panama, tropical forest clearing has eliminated 70% of the forest on the watershed that feeds water to the Panama Canal. Today, as a result, the lakes that supply the 52 million gallons of fresh water that are needed to lift each and every ship through the locks are now filling in with soil washed in by the rain from those deforested areas. Some researchers are predicting that by the time the canal is fully transferred to Panama at the end of the year 1999 it will have become a worthless ditch -- with all sorts of repercussions for the sustainability of Panama's economy (USDA-AID 1980 p. 68). This problem is being taken very seriously by the Panamanian government. Three months ago, General Manuel Noriega called the deforestation of the Panama Canal watershed a matter of national security and placed a five-year ban on the cutting of any tree in Panama older than five years.

Tropical forest destruction can also lead to declines in the amount of rain that falls because rain forests do exactly what their name implies: they make rain. Studies in Panama and in the Brazilian Amazon show that over half of the rain that falls on a tropical rain forest is derived from the forest itself. The leaves of tropical forest vegetation breathe out water vapor that is equal to thousands of gallons of water per acre per day. That evaporated water combines with water vapor from the oceans to create rain. But when the forest is cleared, one-half of that recycling system is destroyed, and the amount of rainfall decreases proportionately, as it already has in some areas of Panama and Brazil. Central Panama, for example, has experienced a 17-inch decline in rainfall over the past 50 years. Because less water rises into the air as vapor, less returns to the land as rain (Caufield 1985, p. 71).

Tropical forest destruction can also threaten the stability and sustainability of human life on our planet. It is now certain that the level of carbon dioxide in the earth's atmosphere is increasing. A host of researchers claim that tropical deforestation carries part of the blame for that increase because burning tropical forests, like burning fossil fuels, adds carbon dioxide to the atmosphere. Along with other gases, this carbon dioxide absorbs part of the

heat that would normally bounce off the earth back into space and dissipate. This causes a warming of the surface of the earth in a process that meteorologists call "the greenhouse effect."

One possible result of that process may be changes in rainfall patterns that could affect crop production throughout the world. We could find ourselves raising wheat in northern Canada and desert goats in Wisconsin. Another result could be a rise of 15 to 20 feet in the world's sea levels. An increase of that magnitude would flood major parts of Florida as well as coastal cities around the world. When you consider that 40% of the world's population lives on a coastline, the repercussions of that are alarming. You might want to refrain from making any investments in beachfront property in Atlantic City. In fact, looking ahead, if you are interested in beachfront property you might consider Pittsburgh or Cincinnati.

It is fair to point out, though, that the emotions that global deforestation can generate have begun to create a backlash among some scientists. And a few scientists are even saying now that the threats to the world's tropical forests have been grossly exaggerated and that rates of deforestation in virgin tropical forest areas are actually quite modest. One thing seems clear to me from these statements: Those people have not been to Latin America. Latin America may be the most critically threatened tropical forest region in the world. The area is losing at least 11,000 square miles of tropical forest every year (Melillo et al. 1985).

Tropical deforestation in Latin America tends to follow a regular three-stage process of road construction, colonization, and cash-crop production. First, bulldozers clear roads through the rain forests to take out valuable hardwood timbers, or to explore for oil, or to establish military control over border areas. Most of the road construction through tropical forests in Latin America begins with logging for hardwoods that end up on international markets in the form of office paneling, boat accessories, or fine furniture.

To get those trees, tropical loggers carry out what they call "high-grading" the forest. There may be as many as 300 to 500 different species of trees on a two-and-a-half-acre plot of tropical forest. This means that, if you are a logger, you are only going to find a few single individuals of any particular tree that you are looking for in that plot. So the loggers bulldoze roads through the forest and spread out feeder roads from these major roads. Then they use metal cables -- draglines -- to drag out the few trees per acre that are commercially valuable to them. That process destroys a certain additional amount of forest. Rain forest trees are tied together at their crowns through an interconnected mass of vines, lianas, and other vegetation, so that when loggers pull down one mahagony tree surrounding trees may come with it. As those trees fall, they destroy the trees they land on. In sum, felling a single mahagony tree results in the destruction of an average of at least 17 other, noncommercial trees (Ng 1982). Adding in the acreage that is cleared for roads, staging areas, and stacking areas, logging operations can destroy 30% of a forest where only a few trees per acre are actually taken out to be sold.

Logging, though, is only one reason for road construction in tropical forests. In Mexico and Central America, roads are being bulldozed through tropical forests for military purposes. One of the best examples is the new Southern Frontier Highway that Mexico is building through the Marques de Comillas, Mexico's only remaining lowland tropical rain forest. The official government document describes the road as one that will "integrate" the rain forest of the state of Chiapas into the national economy by bringing in tens of thousands of new farmers, beef cattle, and beef-packing plants to supply the restaurants of Mexico City. The same document also mentions that this new road will improve the surveillance of the border between Mexico and Guatemala. It is no coincidence that this same area is occupied today by at least 70,000 Guatemalan refugees. This is also the oil-rich region of both countries, and each has accused the other of trying to drill in slant wells to take out the other's oil. To counter

this new road on the Mexican side, the Guatemalans are now building two new roads through their tropical forest, one along the southern border of Chiapas and another one parallel to the Rio Usumacinta.

In South America, roads are being bulldozed for oil exploration, opening up areas of tropical forests that five years ago were inhabited only by indigenous peoples. The jungle highways of Brazil and the impact they have had on Amazonian Indians are already infamous. Farther west, in the Amazon rain forest of Ecuador, oil companies from the United States, France, Brazil, and Argentina are this very day exploring for oil inside Ecuador's largest national park, Yasuni. This park is also the home of the last uncontacted Waorani Indians. You can imagine the impact on a traditional rain forest tribe when bulldozers smash a road through the forest or when helicopters scream across the jungle canopy, land, unload their equipment, and start booming the ground with seismic charges.

Whatever the reason for the initial building of roads through tropical rain forests in Latin America, they consistently introduce the second stage of deforestation: colonization. During this stage, landless farm families from other areas of the country, or sometimes even from other countries, use those roads to filter into the rain forest and colonize it. They are looking for new land for agriculture and new lives for their families.

Some researchers look at these colonizing farm families and call them the major threat to tropical forests. Other researchers will tell you that the only reason these families are in the rain forest in the first place is because the land they should be farming is in the hands of multinational corporations or the nation's wealthy elite. They point out that those groups are using the most fertile land in the country to produce export crops like cotton, bananas, pineapples, oil palm, or beef cattle. The fact that the best agricultural lands are being used to produce export crops means that the growing population of rural farm families gets pushed onto marginal lands such as hillsides or down into lowland tropical forests. In other cases, the Latin American governments actively promote colonization of tropical forests. They do this partly to diffuse demands for land reform in areas that are already in production. They also do it because some politicians feel that forested land is land that is not being used, land that should be cleared and put into production.

In company with those factors is another phenomenon: population growth. Right now there are about 429 million women, men, and children living in Latin America, and that number is expected to double within 32 years. Given Latin America's population growth rates and barring any radical changes in the region's economic structure, you can figure that as long as there are tropical forests still there to colonize, landless farm families are going to continue to migrate into them, clear them, and raise food crops and cash crops.

At the same time, it would be inaccurate to say that Latin America's tropical forests are being cleared simply to raise food and export crops. Land speculation also takes its toll. In Panama, there is a group of professional deforesters who move on to tropical rain forest land that belongs to the national government, clear it, burn it, plant it in grass, and then sell it for $32 an acre to ranchers from Panama City. They then move on to the next plot and repeat the cycle. The ranchers who buy that cleared land are not so much interested in raising cattle as in holding on to the land as a hedge against inflation. The key factor here is that land prices are rising in Panama and Honduras and Brazil just as they are every place else. And land, especially land on a road, increases in value fairly consistently, even as it erodes and grows knee-deep in weeds and ticks. Thus, a farmer or rancher may be losing his shirt trying to raise crops or cattle, but he may simultaneously be making a mint as land values inflate.

In Ecuador, farm families learn where roads are going to be bulldozed for oil exploration or for logging, and they are lined up in the forest when the survey crew arrives with its equipment. Those families can colonize and claim the land for free, and they know that as

quickly as that road is built the land on either side of it will bring them more money than they can earn in years harvesting rice or bananas. By Ecuadorian law, though, a family cannot establish title to a plot of land simply by occupying it. The family is required to clear at least half of it in order to get title and be able to sell it. The government agencies call this "improving" the land. The resulting scene is one of families clearing these lands as quickly as they can so that they can sell it and move on to the next road site. And who can blame them? If someone offered free land on the outskirts of Madison, several of you would be out there lined up tomorrow morning.

The process of deforestation, however, does not stop with colonization. Colonization is followed by a third and final stage of tropical deforestation: the expansion of commercial crops into the rain forests. This, combined with land speculation, is the fundamental driving force behind deforestation. During this third stage, land that has been cleared by colonists is absorbed by a second wave of settlers who follow behind that pioneer front and buy up those small holdings of cleared land. They combine those cleared plots into larger plantations and then use those to produce cash crops.

Historically, the classic cash crops in Latin American tropical areas have been coffee, cacao, bananas, and more recently, African oil palm and citrus fruits. Some of these, being tree crops, can form the basis for the sustainable use of tropical soils. But the most dominant and destructive of these tropical "crops" is beef cattle -- and cattle production is not a sustainable use of tropical soils. Land cleared of tropical forest will produce good beef yields for an average of seven to 10 years before erosion, weeds, and loss of fertility combine to prompt the cattlemen to search for new pastures. In some places, cattlemen simply abandon the worn-out pastures and move farther into the forest. UCLA geographer Susanna Hecht has found that in some regions of the Brazilian Amazon up to 80% of the pasture lands cleared from tropical forests have been abandoned (Hecht 1982). In Mexico and Central America, cattlemen usually try to maintain the old pastures in order to keep title to the land. The yield on those pastures, however, plummets as erosion and nutrient-leaching occur.

The key question to ask, then, is this: Is this wise use of tropical forests and tropical forest soils? To answer that question, consider that the average stocking rate on cleared Central American tropical forests soils is one head of cattle for every four acres of pasture. The average yield is nine pounds of beef per acre per year. Consider also that transforming forest into cattle pasture does not aid the people who live in those deforested areas. Raising cattle requires fewer workers than almost any other form of tropical production. In fact, that lack of need for laborers is one reason that landowners choose ranching in the first place. Keep in mind, too, that the people who eat the beef produced on those cleared tropical forest soils are not the people who live there. Most Central American beef is exported to the cities, where it is eaten by the urban middle class. About a quarter of it, 145 million pounds per year, ends up in the United States, where you and I eat it in the form of hamburgers and hotdogs and TV dinners.

The result of Central America's beef mania has been the most dramatic human-induced environmental change in the region's history. Today, two-thirds of Central America's original tropical forest cover has been eradicated and replaced by a mosaic of crops, pasture land, and regrowth. Today, livestock production consumes two-thirds of all the agricultural land in Central America. In Costa Rica, cattle pasture takes up 70% of the nation's farmland. Seventy-one percent of all the new land brought into production in Costa Rica is converted from forest to pasture. Much of the rest becomes pasture after a couple of years of subsistence cropping. In the tropical forest regions of Nicaragua, pastures consume 90% of all agricultural land. And in the Mexican states of Tabasco and Chiapas, 93% of all agricultural land is in beef cattle pasture (Nations and Leonard 1986).

Jeff Leonard of the Conservation Foundation in Washington, D.C., recently put together two maps of Central America. The first map shows the region's most fertile agricultural soils. Most of those are located in the dry tropical forest region of the Pacific Coast of Central America, the area that biologist Dan Janzen calls the "breadbasket of Central America" because of its rich, deep volcanic soils. The other map shows the areas where cattle pasture comprises more than 50% of all land use. When you overlay the second map on the first, you find that the most fertile agricultural land in Central America is the same land that is being used today to raise beef cattle. The point is that the lands that should be producing food for Central Americans are instead being used to produce cattle, and a quarter of that beef is being exported to the United States -- which is already the largest producer and consumer of beef in the world. Meanwhile, tropical forests are being destroyed by farm families who have been pushed off the good agricultural land, or they are being cleared and burned to raise cattle to send to the cities to replace the beef that has been exported to Gringolandia.

If you define sustainable development as the process of generating economic and social benefits without depleting the natural resources upon which those benefits are based, then you do not have to be an economist to realize that cattle production is not a sustainable use of tropical soils and tropical forests.

All of this information raises several questions: What would be sustainable use of tropical soils? What would be sustainable use of tropical forests? How can people in tropical forest areas feed themselves, produce an income, and improve their lives without eradicating the natural resources that their lives are based on? A number of researchers both here and in Latin America have decided that one of the most promising ways to do this is to learn from the more successful production systems of Latin America's indigenous peoples. Bear in mind that native Americans are the only people who have perfected sustained-yield agriculture on the region's tropical forest soils. The point is that these traditional agricultural systems can play an important role in sustainable development and in tropical forest conservation. The idea is not to investigate indigenous agriculture as a scientific curiosity, but to use it as the basis for developing new, ecologically sound systems of food and cash crop production in tropical forest areas.

Fortunately, many sustained-yield systems are still present in the Latin American tropics. They all share the quality of using small sections of tropical land to produce abundant food crops and abundant cash crops over long periods of time. They also maintain biological diversity and are labor-intensive rather than capital-intensive. But, most important, any number of these systems can be adapted and expanded for the benefit of rural farm families. They can bring improved agricultural yields, increased income, and more sustainable use of tropical forests.

Some of the most famous of these systems include the swidden fallow management of the Bora Indians of Eastern Peru; the soil and forest management system of the Kayapo of Brazil; the orchard gardens of the Guaymi of Panama; and the human-made forest of Yucatan that Arturo Gomez-Pompa calls the pet kot system.

Two other traditional agricultural systems from tropical forest areas of Latin America deserve special consideration. Both of these are from Mexico but have been used throughout the Maya area of Mexico and Central America. The first is a system known as tropical *chinampas*. You may recognize the term from the Mexico City tourist site of Xochimilco. Xochimilco is the remant of an Aztec chinampa system that once covered 50 square miles in the Valley of Mexico and fed tens of thousands of people. Less well known is the fact that the Maya created a thousand square miles of chinampas in the tropical forest regions of Mexico, Guatemala, and Belize. And that system formed the subsistence base of a Mayan civilization that flourished in the tropical forests for nearly 10 centuries. Geographers James Parsons and Bill Denevan, and

later, Kent Mathewson, have identified the remnants of another 700 square miles of raised-field agriculture similar to chinampas in Suriname, Venezuela, Columbia, Ecuador, Peru, and Bolivia.

A tropical farmer can create a chinampa system by digging narrow irrigation-drainage trenches on at least three sides of a cultivated plot in an area where water is available year-round. He deposits that fertile, excavated soil on top of the cultivation plot to raise it above the water table and plants his crops there. He maintains the fertility of the chinampa system by periodically dredging mud from the trenches and adding it to the cultivation plots as organic fertilizer. Aquatic vegetation growing in the canals serves as green manure. As their name implies, the irrigation-drainage canals allow the farmer to control his crops' water supply. He uses those canals to irrigate his crops during the dry season and to drain excess water during the rainy season. As a result, he can maintain year-round production of food and cash crops. As an additional benefit, fish may colonize those canals and provide the farmer with an abundant source of high-quality protein.

Experiments have been conducted on chinampas in tropical forest areas of Veracruz, Tabasco, and Chiapas by Mexico's Institute for the Investigation of Biotic Resouces (INIREB) and by the College of Tropical Agriculture in Cardenas, Tabasco. Both of these institutions demonstrated that tropical chinampas can produce a constant and abundant harvest in areas that were previously thought to be suitable only for wet-crop cultivation or for pasturelands. At Cardenas, experimental chinampas produced food and cash crops for a family of 10 on two-and-a-half acres of land. They can do this year after year without depleting the soil and without requiring the clearing of new tropical forest land. Another benefit of the chinampas system is that the farmer can plant trees along the edges of the canals to hold the soil in place, and depending on the types of trees he selects, he can produce additional food or fibre or fuelwood for his family. Those same trees also serve as a wind barrier for the crops and provide habitat for insect-eating birds.

The upshot of all this is that the chinampa system requires no machinery or insecticides or artificial fertilizers, although the farmer can use any of these if he has them and if he wants to. The system is also compatible with cattle production because the crop residues and weeds can serve as cattle fodder. In exchange, the cattle provide milk and meat, and their manure is added to the cultivation plots as organic fertilizer.

The tropical chinampa system is just one example of the sort of intensive agricultural system that has to be taken from the experimental stage to large-scale use if we expect families in the tropical areas to produce food and income without destroying the natural resources upon which their lives depend. Another example of such a system is the traditional agroforestry system of the Lacandon Maya in Chiapas, Mexico. Agroforestry is a generic term for agricultural systems that produce trees, food crops, and animals on the same units of land, either sequentially or simultaneously. The basic approach of agroforestry is to plant trees *with* crops rather than to continually cut down trees in order to plant your crops.

The Lacandon Maya practice a traditional agroforestry system that combines up to 79 different crop varieties on two-and-a-half-acre plots of cleared tropical forest soil. In Mexico these plots are called *milpas*. The Lacandon create their milpas just as forest farmers do throughout the tropics: They cut the forest and then burn it in order to create the physical space for their crops, to scourge the area of insects and weeds, and to produce a temporarily fertile soil by converting the nutrients in the tropical vegetation into a nutrient-rich ash. To absorb those nutrients before they escape the system, the Lacandon farmer plants such fast-growing tree crops as chayote, papaya, bananas, and plantains, and root crops such as manioc, sweet potatoes, and the new-world taro plant known as macal or Xanthosoma. After planting those initial nutrient-grabbing crops, the family goes on to plant another 75 different kinds of food and fibre crops during the course of the agricultural year.

In addition to the crops that the family actively plants, the milpa includes a second component consisting of natural forest crops that sprout in the milpa and that the farmer recognizes and allows to grow as crops. These spontaneous crops include food plants such as wild tamarind, mamey, wild pineapple, wild dogbane, and wild sugar vine, and raw material plants such as balsa wood and cork wood that are used for housing, twine, bark cloth, and bows and arrows.

Lacandon farmers recognize the benefits they gain by maintaining this biological diversity in their milpas. By planting a variety of crop species and by dispersing them throughout the milpas, the farmer helps prevent the mass outbreaks of disease and insect pests that normally plague monoculture crops in tropical areas. That diversity also provides a variety of food and fibre crops because different plants produce different edible or usable parts during different times of the year. One added benefit of the diversity of the milpas is that it attracts edible mammals. Pacas, peccaries, and deer are attracted to the food crops in the milpas, and the farmer will purposely plant more of those crops than he knows he is going to need in order to feed those wild animals. He knows that in doing so he is creating a productive hunting area that will provide his family with meat protein. In fact, studies in several areas of the Latin American tropics indicate that the presence of milpas in a tropical forest may actually increase the populations of certain wild animals in that area.

The most important point about the Lacandon system, and the reason that it should interest planners and conservationists, is the fact that Lacandon families maintain this system on the same plot of cleared forest land for five to seven consecutive years. By contrast, most of the immigrant farm families that are moving down into the lowland forest end up clearing new agricultural plots every year.

Another important point about the Lacandon system is that the farmer does not abandon the old cultivation plot when he clears a new one. He plants it with tree crops -- rubber, cacao, citrus, avocado -- and continues to harvest the area for five to 15 years while it regrows with natural forest species. The Lacandones call these areas *pak che kol*, which means "planted tree garden." When the natural forest species finally overtake those tree crops, the farmer clears the plot again and begins the cycle anew.

In a nutshell, then, the Lacandon agroforestry system cycles food and forest continually on small plots of forest land. The tropical forest becomes a milpa, which becomes a planted tree garden, which becomes tropical forest, which becomes a milpa again, and so on through time. By using that system, a traditional Lacandon farmer may clear as few as 25 acres of tropical forest in his entire agricultural career, from the age of 18 to the age of 70.

Because of that cycling system, Lacandon agroforestry is highly productive and ecologically sound. It is productive because the farmer can produce up to 5,000 pounds of shelled corn per acre per year and an equal amount of root crops, tree crops, and vegetable crops. It is ecologically sound because its diversity makes it resistant to disease and insect pests and because it is minimally destructive to the tropical forest. By contrast, the extensive beef cattle production that is replacing the Lacandon Maya system produces nine pounds of beef per acre per year and destroys the tropical forests in the process. Most of that beef is exported out of the area.

A few years ago I tried to explain the benefits of the Lacandon system to a Mexican engineer who was charged with developing sustainable agricultural systems for the Chiapas jungle. He listened politely, but it was obvious that his mind was already filled with visions of agribusiness and cattle production. He told me that the Lacandon system was very interesting, but it was not "modern." "Instead," he said, "we must teach the Lacandones how to farm in the tropical forest."

My point then was the same as it is now: Rather rather than eradicate indigenous systems like that of the Lacandon Maya in a search for something "modern", we should be work with these indigenous people to create systems that are sustainable. The point is not that pioneer farm families are going to move into the tropics and adopt the Lacandon agricultural system and live happily ever after. But by analyzing indigenous systems like those of the Lacandon and the Bora and the Kayapo and the Guaymi, by experimenting with them, and by adapting certain features that they offer, we can create new agricultural systems that produce higher food yields and higher incomes and simultaneously work for the conservation of tropical forest resources. This is exactly what Mexican and United States researchers are trying to do when they work with tropical chinampas. This is what the staff of INIREB is doing when it tries to recreate Lacandon agroforestry plots in other states of Mexico. Providing technical and financial support for these efforts may do more to conserve tropical forests than any other activity in conservation.

The biggest problems we face in promoting these systems are not technical or biological, but problems of funding and attitude. An economist at the World Bank once told me that systems like tropical chinampas and agroforestry are all very pretty, but they are not "economical." This was one of the same economists who used to tell us that raising beef cattle on cleared forest lands *is* economical. In social science, we call this coming to believe the "often-repeated lie." Well, the best counter to the often-repeated lie is the often-repeated truth, and the truth is that traditional agriculture can be as economically sound as it is sustainable.

That is not to say that it is going to be cheap to put these adapted systems into production over wide areas of the tropics. That is going to require funding for research on existing indigenous systems and research on socioeconomic factors such as extension work, market development, and short-term and long-term incentives. We need to remember that colonizing farm families will not change their agricultural practices simply to benefit wildlife in tropical forests. They *will* adopt new practices if they can improve their lives and their incomes. Demonstrating that fact should be one of our most important priorities. The message here is that sustainable development and the conservation of tropical forests take place simultaneously. They are, in fact, two sides of the same coin.

There are a number of positive things like this happening on all sorts of fronts around us. During the past 10 years, for example, we have seen the creation of 47,000 square miles of new national parks in Colombia, Brazil, Ecuador, Bolivia, and Venezuela. One of the key features of those parks is that they are incorporating indigenous peoples and local communities into their planning and operation in a movement in conservation that is called "parks and people."

Another facet of that movement is the development of conservation tourism. Tourism is today the second largest industry in international trade, just after oil and just edging out the arms trade, which is in third place. Tourism generates at least $95 billion annually worldwide, and increasingly, tourists are looking for unspoiled natural areas. Tropical forests are one of their favorite spots. The Kuna Indians in Panama, to cite one example, are learning that conservation tourism can be a sound, sustainable basis for a community's economy and for protecting their tropical forests at the same time.

Another amazingly positive step occurred last week when conservationists in the United States bought $650,000 worth of Bolivia's $4 billion foreign debt; in exchange, the Bolivian government set aside a 6,000-square-mile tropical forest nature reserve. Those conservationists have used the debt crisis, which normally makes environmental problems worse, to help solve the problem of tropical forest destruction. Legislation is now in place in the United States Senate that will allow commercial banks to get tax credits when they forgive debts of countries that agree to protect ecologically important lands. So write your congressman.

Robert Goodland probably told you last week about the new environmental sensitivity that is growing inside the World Bank, which until recently had a frightening record of funding projects that destroyed tropical forests. He may also have mentioned that Wisconsin's Senator Robert Kasten has been one of the key figures in convincing the World Bank, and more recently the InterAmerican Development Bank, to hold back funds for destructive projects. And behind Senator Kasten is a whole crew of citizens and environmentalists who have been pushing the multilateral development banks to change their views on what is and what is not sustainable development in tropical forest areas.

The point is that positive changes are happening all around us. I am not trying to say that things are great, that the battle is over, and that tropical forests are saved. Far from that. Tropical forests are being eradicated faster than ever. Some positive trends are developing, but even more needs to be done. We need to know more about how land tenure systems prompt people to destroy forest resources. We need to identify laws that are working against, rather than for, sustainability. We need to know more about traditional agricultural systems and about how to transform them into new sustainable systems of crop production. And we need to know more about the plant and animal species that are in tropical forests in the first place.

Don't let anybody try to tell you that the experts have it all figured out and they don't need your help and you don't have to worry about it. Nobody knows more about it than you do, or at least any more about it than you can learn with some serious library research and some intensive fieldwork.

Don't get lulled into thinking that tropical forests are not important to your life because they are so far away. That is akin to thinking that germs can't hurt you because you can't see them. If we work with the citizens of the tropical nations we can learn to use tropical forests sustainably and we can help make them a part of a sustainable economy on this planet. We can do that if we are willing to work together to study these complex problems and then to act on them. You can do it if you are willing to write your congressmen and tell them what you think of the World Bank's Polonoeste project. You can do it if you are willing to call up Houston businessmen and ask them why they are clearing rain forests for pasture in Belize. And you can do it if you are willing to help slow population growth by working to improve the status of women in the developing world. But you cannot do it if your goal in life is to get a fat job and a fur coat and a BMW with a cellular phone and a bumper sticker that says "Born to Shop."

At issue is the future of the tropical world and all the benefits we gain from it. We can conserve the world's tropical forests if our vision is of a world where destroying our fellow species is a violation of our own rights as living creatures, a world where human beings and the creatures with which we share it can live together sustainably, dependent on one another and benefiting one another as long as the earth continues to turn. That is the vision that I would like to see us leave this room with tonight.

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In Defense of Development

Julian Simon

Let me begin with a question: How many of you think that with respect to natural resources, conditions have been improving over the past few decades? Now, how many of you think that things have been getting worse with respect to natural resources and the environment? It is very clear from your show of hands that I am not preaching to the converted. That will not be a problem tonight. How many of you think that, aside from the short-term effects, population growth has had positive economic effects? Raise your hands. A few more around. How many of you think that population growth has had negative economic effects?

The message you get from reading the popular literature is that things have been getting worse and that population growth is responsible. For example, the *Global 2000 Report* to President Carter in 1980 made it official that the world is going to hell in a handbasket. As *Time* magazine said, "The U.S. government has added its full voice to the chorus of environmental Cassandras. . . a presidential panel warns that time is fast running out for averting a global calamity." But I shall try to show you that, when we raise our gaze from the frightening articles in the newspaper about today and yesterday, we can see that life has been getting better over the last centuries and decades, here in the United States as well as in the rest of the world, in most of the important material aspects of our lives. And there is no persuasive reason to believe that these trends will not continue indefinitely.

Before moving on to the evidence, I wish to state a qualification that tends to get overlooked: I do not say that all is well everywhere, and I do not predict that all will be rosy in the future. Children are hungry and sick; people live out lives of physical or intellectual poverty and lack of opportunity; war or some new pollution may finish us off. What I *am* saying is that for most relevant economic matters I have checked, aggregate trends are improving rather than deteriorating. Also, I don't say that a better future happens automatically or without effort. It will happen because men and women will struggle with problems with muscle and mind and will probably overcome, as people have overcome in the past -- if the social and economic system gives them opportunity to do so.

Let's quickly review a few data on how human life has been doing.

Life can't be good unless you are alive. Plentiful resources and a clean environment have little or no meaning to us unless we and others are alive to enjoy them. The most important and startling demographic fact -- in my view, the greatest miracle in human history -- is the decrease in the world's death rate. Recall that it took thousands of years to increase life expectancy at birth from the low of 20 years to the high 20s. Then, in just the last two centuries, the length of life you could expect for your baby or yourself in the advanced countries jumped from less than 30 years to perhaps 75 years. What greater event has humanity witnessed? And just since World War II, the length of life one could expect in the poor countries has leaped upwards by perhaps 15 years due to advances in agriculture, sanitation, and medicine. Is this not an astounding triumph for humankind?

These facts have different meanings for others, however. For example, in the *Washington Post* recently there was a story headed "Chinese Statistics Indicate Killing of Baby Girls Persists." That sounds terrible. But in the body of that article we read, "Life expectancy is now 69 years for Chinese women and 66 for men, an increase of 20 years over the past three decades." What could be a more extraordinary good-news story than that fact -- unless one wishes there were fewer Chinese? Yet the headline is negative.

About pollution now: How many of you think that Europe and the U.S. have been getting more polluted in recent years? Please raise your hands. Less polluted? The evidence (fig. 1) shows that with respect to air, the EPA's Pollutant Standards Index has been improving since its inauguration in 1974.

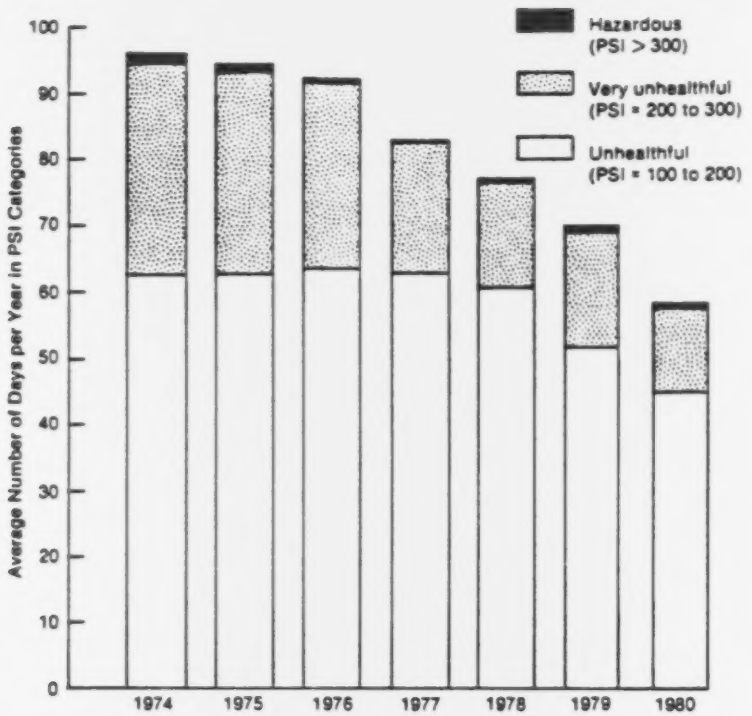

Figure 1. Air quality in 23 metropolitan areas, 1974-1980, as measured by the Pollutant Standards Index (PSI). Source: Council on Environmental Quality

The main pollutant particulates have declined since at least 1960. With respect to water, the proportion of places in the U.S. with water of good drinkability has increased since the data began in 1961.

Now let's talk about natural resources.

Natural resource scarcity -- as measured by the economically meaningful indicator of cost or price -- has been decreasing rather than increasing in the long run for all raw materials with the outstanding exception of oil. I'll show this effect for copper (fig. 2), which is representative of all the metals.

And this trend of falling prices of copper has been going on for a very long time. From the 18th century B.C. in Babylonia under Hammurabi -- almost 4,000 years ago -- until a thousand years later, the price of iron fell to a fifth of the early price, and the price of copper fell with it, due to the development of cheap iron tools to replace copper tools. Copper then lost about a thousand times its price in the U.S. now, relative to wages.

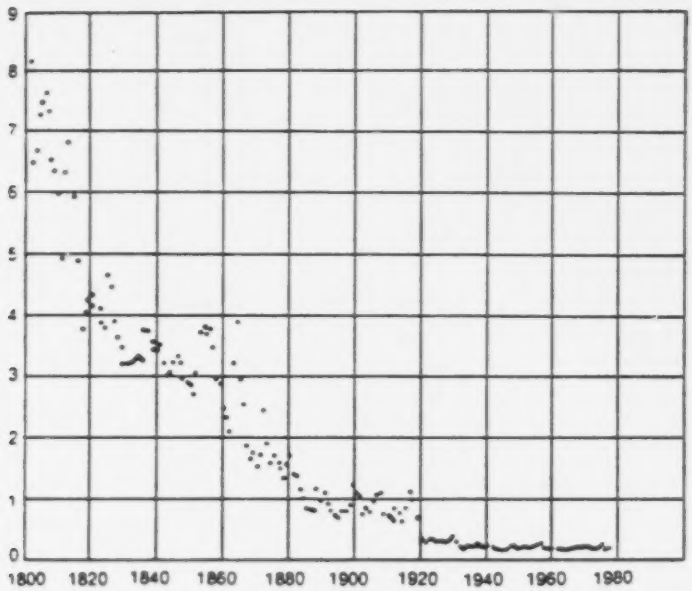

Figure 2. The scarcity of copper as measured by its price relative to wages. Source: Historical Statistics of the U.S.

Regarding oil, the price rises starting in 1973 were purely political. The cost in the Persian Gulf still is perhaps 15 cents to 25 cents per barrel. There is no reason to believe that the supply of energy is finite or that the price of energy will not continue its long-run decrease forever. I realize that it sounds strange to you to say that the supply of energy is not finite or limited, but so it is. I'll be delighted to give you a whole routine on this in the question-and-answer period.

Food is an especially important resource. How many of you think that the world's food situation has been getting better? Raise your hands. Getting worse? The evidence is particularly strong that we are on a positive trend despite rising population. The long-run price of food relative to wages (fig. 3), and even relative to consumer products (fig. 4), is down due to increased productivity.

Famine deaths have decreased in number even though population has increased greatly over the past century. Per-person food consumption is up over the past 30 years. Africa's food production per person is down, but by 1987 we all know that that has nothing to do with the physical conditions but instead clearly stems from governmental and other social conditions.

In evaluating what I have to say compared to the messages of others, I hope that you will keep these points in mind:

1. The message that I give you about food, especially, is not a minority message; rather, it is the settled wisdom of expert agricultural economists all over the world. It is only a few effective publicists of doom, and the newspaper reports that sell newspapers, that keep repeating the forecasts of hunger and famine.

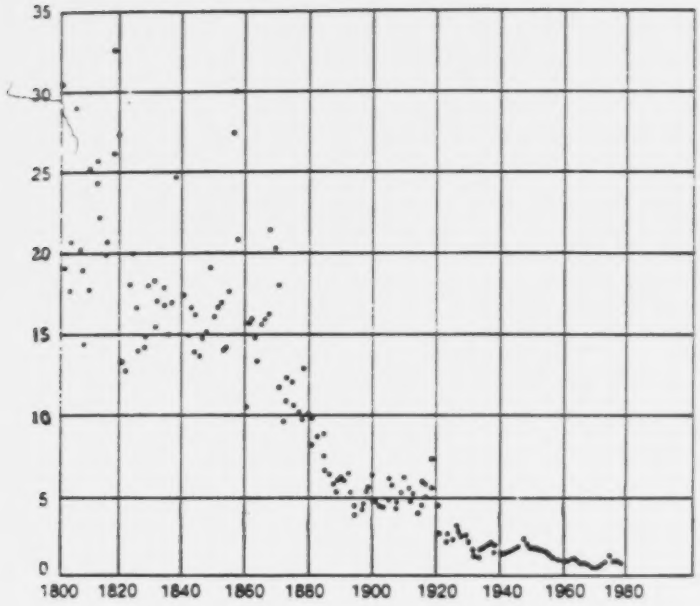

Figure 3. The price of wheat relative to wages in the U.S.
Source: Historical Statistics of the U.S.

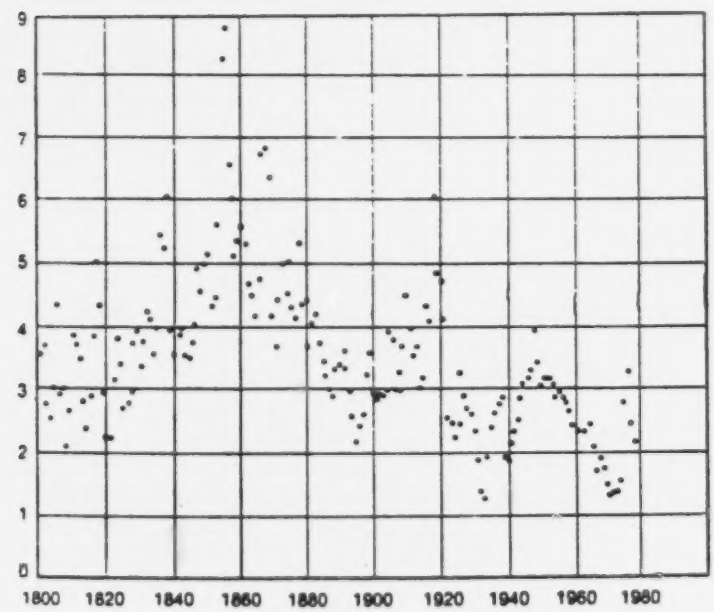

Figure 4. The price of wheat relative to the consumer price index
Source: Historical Statistics of the U.S.

2. There has been a major shift toward the point of view that I advocate. Last year the National Academy of Sciences presented its first report on population growth and development since 1971 and moved about 80% away from its former scary conclusions.

3. I have been offering the same point of view since the beginning of the environmental panic in 1970, and all of the forecasts deriving from this general point of view have turned out to be right: better nutrition in the world rather than more hunger; no oil shortage; falling prices of raw materials; falling farmland prices; debunking the urbanization-of-farmland and soil-erosion scares in the United States; and so on. Every single one of the forecasts has been validated either by how events turned out or, in the case of farmland and soil erosion, by subsequent research. In contrast, all of the doomsday forecasts of Famine 1975, the death of Lake Erie and the oceans, millions choking to death in the U.S. of air pollution, $3-per-gallon gasoline; wheat prices doubling, etc., have turned out to be wholly wrong. The curious part is that the "prophets" who made all those wrong predictions continue to be listened to in 1987.

The trend toward a better life can be seen in most of our own families if we look. For example, I have mild asthma. Recently I slept in a home where there was a dog, and in the middle of the night I woke up with a bad cough and shortness of breath. When I realized it was caused by the dog dander, I took out my $12 inhaler, good for 3,000 puffs, and took one puff. Within 10 minutes my lungs were clear. A small miracle! Forty years ago I would have been sleepless and miserable all night, and I would have had to give up the squash-playing that I love so much because exercise causes my worst asthma in the absence of an inhaler. Or consider diabetes. If your child had diabetes a hundred years ago, you had to watch helplessly as the child went blind and died early. Now injections, or even pills, can give the child almost as long and healthy a life as other children. Or glasses. Centuries ago you had to give up reading when your eyes got dim when you got to be 40 or 50. Now you can buy glasses at the drug store for $9. And you can even wear contact lenses for eye problems and keep your vanity intact. Is there not some condition in your family that in earlier times would have been a lingering misery or a tragedy, but nowadays our increasing knowledge has rendered it easily bearable?

Concerning population growth: Yes, more consumers mean less of the fixed available stock of goods to be divided among more people. And more workers laboring with the same fixed, current stock of capital means there will be less output per worker. The latter effect, known as the law of diminishing returns, is the essence of Malthus's theory as he first set it out.

But if the resources with which people work are not fixed over the period being analyzed, then the Malthusian logic of diminishing returns does not apply. And the plain fact is that, given some time to adjust to shortages, the resource base does not remain fixed. People create more resources of all kinds.

When we take a long-run view, the picture is different from, and considerably more complex than, the simple short-run view of more people implying lower average income. In the very long run, more people almost surely implies more available resources and a higher income for everyone. Do you think that our standard of living would be as high as it is now if the population had never grown from about four million human beings perhaps 10,000 years ago? I don't think we'd now have electric light or gas heat or autos or penicillin or travel to the moon or our present life expectancy of over 70 years at birth in rich countries, in comparison to the life expectancy of 20 to 25 years at birth in earlier eras, if population had not grown to its present numbers.

Let's now consider the happy evidence that contradicts the standard alarming reports.

There now exist perhaps a dozen competent statistical studies, beginning in 1967 with an analysis by Nobel prize winner Simon Kuznets covering the few countries for which data are available over the past century, and also analyses by Kuznets and Richard Easterlin of the data covering many countries since World War II. The basic method is to gather data on each country's rate of population growth and and its rate of economic growth and then to examine whether, looking at all the data in the sample together, the countries with high population growth rates have economic growth rates lower than average and countries with low population growth rates have economic growth rates higher than average. The clear-cut consensus of this body of research is that faster population growth is not associated with slower economic growth.

Of course, one can adduce cases of countries that seemingly are exceptions to the pattern. The genius of statistical inference, however, is that it enables us to draw valid generalizations from samples that contain such wide variations in behavior. The exceptions can be useful in alerting us to possible avenues for future analysis, but as long as they are only exceptions, they do not prove that the generalization is not meaningful or useful.

Please notice that this body of literature is now almost two decades old, that the research is by scientists with the best possible credentials (many of whom expected to find a negative effect), and that it has been published in well-known scientific journals. Yet not a single one of these studies is commonly mentioned in discussions of population growth. One wonders: Why not? I do not have an answer to the question.

One may wonder whether population density is a more meaningful variable than population growth. Indeed, such studies have been done. And again, the statistical evidence directly contradicts the common-sense conventional wisdom. If you make a chart with population density on the horizontal axis and either income level or the rate of change of income on the vertical axis, you will see that more people per square kilometer is associated with better, rather than poorer, economic results.

Check for yourself: Fly over Hong Kong -- just a few decades ago a place seemingly without prospects because of insoluble resource problems -- and you will marvel at the astounding collection of modern high-rise apartments and office buildings. Take a ride on its excellent smooth-flowing highways for an hour or two and you will realize that a very dense concentration of human beings does not prevent comfortable existence and exciting economic expansion as long as the economic system gives individuals the freedom to exercise their talents and to take advantage of opportunities. And the experience of Singapore demonstrates that Hong Kong is not unique. Two such examples do not prove the case, of course. But these dramatic illustrations are backed by the evidence from the aggregate sample of countries and, hence, do not mislead us.

Hong Kong is a special thrill for me because I first saw it in 1955 when I went ashore from a U.S. Navy destroyer. At the time I felt great pity for the thousands who slept every night on the sidewalks or on small boats. It then seemed clear to me, as it must have to almost every observer, that it would be impossible for Hong Kong to surmount its problems -- huge masses of impoverished people without jobs, total lack of exploitable natural resources, more refugees pouring across the border each day. But upon returning in 1983, I saw bustling crowds of healthy, vital people full of hope and energy. No cause for pity now.

Now that you have heard most of the data I have to offer, I wonder: Do any of you who had such negative views of our resource and environmental situations have any different thoughts about the matter now? Please raise your hand if your thinking has changed substantially on the

subject. The tough question for me is, why is what you have heard from the others more convincing? Is it that their presentations are inherently more convincing? Or is it that you have heard so much of these ideas in the past?

Let us consider how it comes about that history reveals increasing availability rather than decreasing availability of resources. Let's consider the process by which this comes about: England was full of alarm in the 1600s at an impending shortage of energy due to the deforestation of the country for firewood. People feared a scarcity of fuel for both heating and for the iron industry. This impending scarcity led to the development of coal.

Then in the mid-1800s Englishmen came to worry about an impending coal crisis. The great English economist, Jevons, calculated that a shortage of coal would bring England's industry to a standstill by 1900; he carefully assessed that oil could never make a decisive difference. Triggered by the impending scarcity of coal (and of whale oil, whose story comes next) ingenious profit-minded people developed oil into a more desirable fuel than coal ever was. And in 1987 we find England exporting both coal and oil.

Another element in the story: Because of increased demand due to population growth and increased income, the price of whale oil for lamps jumped in the 1840s, and the U.S. Civil War pushed it even higher, leading to a whale oil "crisis." This provided incentive for enterprising people to discover and produce substitutes. First came oil from rapeseed, olives, linseed, and camphene oil from pine trees. Then inventors learned how to get coal oil from coal, a flourishing industry in 1859. About then, other ingenious persons produced kerosene from the rock oil that seeped to the surface, a product so desirable that its price then rose from $0.75 a gallon to $2.00. This stimulated enterprisers to increase the supply of oil, and finally Edwin L. Drake brought in his famous well in Titusville, Pennsylvania. Learning how to refine the oil took a while. But in a few years there were hundreds of small refiners in the U.S., and soon the bottom fell out of the whale oil market, the price falling from $2.50 a gallon or more at its peak around 1866 to well below a dollar.

There is one more crucial factor still to be mentioned -- the economic and social system. It has long been considered bad form when discussing economic development to mention economic and social systems. But by 1987 there is solid evidence that an enterprise system works better than does a planned economy. And under conditions of freedom, population growth poses less of a problem in the short run, and brings many more benefits in the long run, than under conditions of government control.

To illustrate, we can compare China with Singapore. China's coercive population policy, including forced abortions, is often called "pragmatic" because its economic development supposedly requires population control. But contrast Singapore. Despite its very high population density -- much higher than China's -- Singapore now suffers from a labor shortage and imports workers. It is even considering incentives for middle-class families to have more children in contrast to its previous across-the-board antinatality policy. This raises the question of whether there are economic grounds for China to even ask people to have only one child.

Tables 1 through 5 compare pairs of countries that have the same culture and history and had much the same standard of living when they split apart after World War II. The first line in the table 1 shows that in each case the centrally planned communist country began with less population "pressure," as measured by density per square kilometer, than did the market-directed noncommunist country. And the communist and noncommunist countries in each pair started with much the same birth rates and population growth rates.

The tables make abundantly clear, despite the frequent absence of data for the centrally planned countries, that the market-directed economies have performed much better economically,

no matter how you measure economic progress. Income per person is higher. Wages have grown faster. Key indicators of infrastructure such as telephones per person show a much higher level of development. And indicators of individual wealth and personal consumption, such as autos and newsprint, show enormous advantages for the market-directed enterprise economies compared to the centrally planned, centrally controlled economies. Furthermore, birth rates fell at least as early and as fast in the market-directed countries as in the centrally planned countries.

Table 1. Population density and growth, selected countries, 1950-83

	East Germany	West Germany	North Korea	South Korea	China	Taiwan	Hong Kong	Singapore	USSR	USA	India	Japan
Population per Sq. Km., 1950	171	201	76	212	57	212	2236	1759	8	16	110	224
% Change in Pop., 1950	1.2	1.1	-7.8	0.1	1.9	3.3	-10.4	4.4	1.7	1.7	1.7	1.6
% Change in Pop., 1955	-1.3	1.2	3.5	2.2	2.4	3.5	4.9	4.9	1.8	1.8	1.9	1.0
% Change in Pop., 1960	-0.7	1.3	3.0	3.3	1.8	3.1	3.0	3.3	1.8	1.7	2.0	0.9
% Change in Pop., 1970	-0.1	1.0	3.0	2.4	2.4	2.2	2.2	1.7	1.0	1.1	2.2	1.3
% Change in Pop., 1983	-0.3	-0.2	2.1–2.6	1.4–1.6	1.3–1.6	1.8	1.5	1.2	0.7–0.9	0.9	2.1–2.2	0.6

SOURCES: Population per square km.: United Nations Educational, Scientific, and Cultural Organization, *UNESCO Yearbook* (1963, pp. 12–21). Percentage change in population: U.S. Department of Commerce, *World Population* (1978); United Nations, Report on *World Population* (1984).

Table 2. Real income per capita, selected countries, 1950-82

	East Germany	West Germany	North Korea	South Korea	China	Taiwan	Hong Kong	Singapore	USSR	USA	India	Japan
Real GDP per capita, 1950[a]	1480	1888	n.a.	n.a.	300	508	n.a.	n.a.	1373	4550	333	810
Real GDP per capita, 1960	3006	3711	n.a.	631	505	733	919	1054	2084	5195	428	1674
Real GDP per capita, 1970	4100	5356	n.a.	1112	711	1298	2005	2012	3142	6629	450	4215
Real GDP per capita, 1980	5532	6967	n.a.	2007	1135	2522	3973	3948	3943	8089	498	5996
Real GNP per capita, 1950[b]	Same as W. Germ.	2943	Same as S. Korea	193	n.a.	417	1053	n.a.	n.a.	7447	217	649
Real GNP per capita, 1960	n.a.	3959	n.a.	473	n.a.	429	979	1330	n.a.	8573	220	1403
Real GNP per capita, 1970	6584	6839	556	615	556	868	1807	2065	4670	10769	219	4380
Real GNP per capita, 1982	9914	11032	817	1611	630	2579	5064	5600	5991	12482	235	9774

[a]Figures for real gross domestic product (GDP) per capita are based on 1975 international prices.
[b]Figures for real gross national product (GNP) per capita are based on 1981 constant U.S. dollars.
SOURCES: Real GDP per capita: Summers and Heston (1984). Real GNP per capita: International Bank for Reconstruction and Development (IBRD), *World Tables* (1980). GNP deflator: Council of Economic Advisers (1986, Table B–3).

Table 3. Life expectancy and infant mortality, selected countries, 1960-82

	East Germany	West Germany	North Korea	South Korea	China	Taiwan	Hong Kong	Singapore	USSR	USA	India	Japan
Life Expectancy at Birth, 1960	68	69	54	54	53	65	65	64	68	70	43	68
Life Expectancy at Birth, 1982	73	74	65	68	67	73	76	73	69	75	55	77
Infant Mortality, 1960	39	34	78	78	165	32	37	35	33	26	165	30
Infant Mortality, 1982	12	12	32	32	67	18	10	11	28	11	94	7

SOURCE: IBRD, *World Development Report* (1985, pp. 260–61).

Table 4. Industrialization and urbanization, selected countries, 1960-82

	East Germany	West Germany	North Korea	South Korea	China	Taiwan	Hong Kong	Singapore	USSR	USA	India	Japan
% Labor Force in Agric., 1960	18	14	62	66	n.a.	n.a.	8	8	42	7	74	33
% Labor Force in Agric., 1980	10	4	49	34	69	37 (1978)	3	2	14	2	71	12
% Urbanized, 1960	72	77	40	28	18	58	89	100	49	70	18	63
% Urbanized, 1982	77	85	63	61	21	70 (1980)	91	100	63	78	24	78

SOURCES: Labor force in agriculture: IBRD, *World Development Report* (1985, pp. 258–59). Urban population: IBRD, *World Development Report* (1985, pp. 260–61).

Table 5. Education and consumption, selected countries, various years

	East Germany	West Germany	North Korea	South Korea	China	Taiwan	Hong Kong	Singapore	USSR	USA	India	Japan
Higher Education Enrollment, 1960	16	6	n.a.	5	n.a.	n.a.	4	6	11	32	3	10
Higher Education Enrollment, 1982	30	30	n.a.	22	1	n.a.	12	10	21	56	9	31
Newsprint per Person, 1950–54	3.5	5.1	n.a.	0.6	n.a.	0.9	4.3	n.a.	1.2	35.0	0.2	3.3
Newsprint per Person, 1982	9.6	21.5	0.1	5.8	1.2	n.a.	16.4	32.1	4.5	44.1	0.4	24.0
Telephones per 100 Pop., 1983	20.6	57.1	n.a.	14.9	0.5	25.8	38.2	36.7	9.8	76.0	0.5	52.0
Autos per 100 Pop., 1960	0.9	8.2	n.a.	0.1	0.005	0.1	1.0	4.2	0.3	34.4	0.1	0.5
Autos per 100 Pop., 1970	6.7	24.1	n.a.	0.2	0.018	n.a.	2.8	7.2	0.7	43.9	0.1	8.5
Autos per 100 Pop., 1984	18.9	41.3	n.a.	1.1	0.010	3.1	4.6	9.3	3.9	55.5	0.2	22.8

SOURCES: Higher education: IBRD, *World Development Report* (1985, pp. 266–67). Newsprint: *UNESCO Yearbook* (1963, pp. 400–409). Telephones: U.S. Department of Commerce, *Statistical Abstract* (1986, p. 845). Automobiles: Motor Vehicle Manufacturers Association of the U.S. Inc., *World Motor Vehicle Data* (various years).

China's problem is not too many children but, rather, a defective political-economic system. With free markets, China might soon experience the same sort of labor shortage as Singapore -- which is vastly more densely settled and has zero natural resources. (And this does not mean a "free" system such as China is talking about now; it is quite unlikely that a truly free market can coexist with a totalitarian political system because a free economy is too great a political threat.)

The most important benefit of population size and growth is the increase it brings to the stock of useful knowledge. Minds matter economically as much as, or more than, hands or mouths. Progress is limited largely by the availability of trained workers.

Even the most skilled persons require, however, an appropriate social and economic framework that provides incentives for working hard and taking risks, enabling their talents to flower and come to fruition. The key elements of such a framework are economic liberty, respect for property, and fair and sensible rules of the market that are enforced equally for all. And at the heart of a free, market-directed economic system, according to Frederick Hayek, the greatest living expositor of such a system, are two general institutions: privateness of property and the family. They are both necessary for economic development. And an unfree, centrally directed socialist system will necessarily prevent the free existence of these two institutions.

So to sum up: In the short run, all resources are limited. An example of such a finite resource is the amount of attention that you will devote to what I have to say today! The longer run, however, tells a different story. The standard of living has risen along with the size of the world's population since the beginning of recorded time. There is no convincing economic reason why these trends toward a better life should not continue indefinitely.

I hope you will now agree that the long-run outlook is for a more abundant material life rather than for increased scarcity, both in the U.S. and in the world as a whole. Of course, such progress does not come about automatically. And my message certainly is not one of complacency. In this I agree with the doomsayers that our world needs the best efforts of all humanity to improve our lot. I part company with them in that they expect us to come to a bad end despite the efforts we make, whereas I expect a continuation of successful efforts. And I believe that their message is self-fulfilling because if you expect your efforts to fail because of inexorable natural limits, you are likely to feel resigned, and therefore to literally resign.

But if you recognize the possibility -- in fact, the *probability* -- of success, you can tap large reservoirs of energy and enthusiasm. Adding more people causes problems, but people are also the means to solve these problems. The main fuel to speed the world's progress is our stock of knowledge, and the brake is our lack of imagination. The ultimate resource is people, especially skilled, spirited, and hopeful young people, who will exert their wills and imaginations for their own benefit and so, inevitably, for the benefit of us all.

Global Balances in the 21st Century

Russell W. Peterson

It's great to be alive. And it's great to be here in Madison with you, my fellow travelers -- travelers on planet Earth with five billion other *Homo sapiens*, all linked together with millions of other species, all dependent on each other and on the air, water, land, and sun.

It took aeons and an infinite number of biochemical experiments before Earth, with the aid of solar energy, was able to put together this current stew we call the biosphere. Some now consider this earth-encircling assembly of plants and animals and the atmosphere, waters, and soils as one organism, a living planet, with each member of the populations of the many species a component of the whole, the vast assembly recycling and regenerating its vital components and creating and regulating its life-supporting atmosphere.

Whatever the explanation, we must admit our biosphere is a glorious place in which to live -- in fact, it is the only known place in which to live. Regardless of how one views the whole, one must agree that we are a unique component, possessor of the most remarkable invention of all, the human brain. It will come in handy as we consider how we might help to save the creation -- not from some invader, but from ourselves -- for clearly it is the cumulative action of humans that is most threatening.

Environmental Leadership

My assignment tonight is to talk about "Global Balances in the 21st Century" and what choices we have for insuring that those balances will provide a decent sustainable quality of life for future generations. And the most important choice to be made is what we will do as individuals in our own lives. Will we devote our abilities, our energy, our time exclusively to furthering our material well-being or improving our status? Or will we dedicate part of ourselves to enhancing the future of life on planet Earth?

Many of you out there have already made the latter choice. The cumulative impact of millions of individuals around the world working to enhance the lives of future generations can save the biosphere. And working in such a cause can bring a great current reward: the self-fulfillment that comes from contributing of one's self in a meaningful way.

Yes, friends, our top choice should be to become personally involved, to stand up and be counted, to speak out for what we believe, and to raise hell with what is wrong.

Leaders who make the big decisions in both public and private life, especially in democracies, cannot survive unless their constituencies give their decisions legitimacy. Unfortunately, this legitimacy is often provided by silence, by failure of constituents to stand up and speak out on what they know is wrong.

One recent example of the people speaking out to block a governmental initiative was in an area of special relevance to my speech tonight, the environmental area. When President Reagan set out to dismantle the environmental regulations and institutions in our country, the environmental citizens organizations organized a nationwide grassroots lobbying effort to get the Congress to block most of the president's antienvironment programs. This effort forced out of office the president's two principal aides on environmental matters, James Watt and Anne Gorsuch-Burford. Such action was possible because the people who overwhelmingly support strong environmental protection made their views known.

The administration bases its antienvironmental actions on the false ideology that environmental regulations are bad for the economy. On the contrary, more jobs and business opportunities have been created by such regulations than have been lost as a result of them (Leung and Klein 1975). I first became aware of this when, as head of the President's Council on Environmental Quality in the Ford Administration, I helped launch the Environmental Industry Council, an organization of businesses that develop and market equipment and processes for cleaning up the environment.

This false ideology continues to plague the country as the president applies it in arguing against legislation to reduce acid rain, in opposing energy efficiency standards, in promoting drilling for gas and oil in ecologically sensitive natural areas, and in refusing to support the Law of the Sea, to mention only a few examples.

To help insure that the world environment is kept livable, we must restore our world leadership on environmental issues.

Most leaders of government, like most leaders of industry and finance and not a few leaders in the academic community, are bogged down with matters of the moment. Getting reelected next election, maximizing this year's operating income, avoiding antagonizing legislatures and other current funders -- these are the forces that have the most impact on our decisionmaking.

And scientists, with few exceptions, plagued by the self-imposed restraints of their disciplines, refuse to enter the public debate about the consequences of their findings. It is time to change this, to look to the longer-range future, to work together toward a saner, safer world. If the problems facing us today are unprecedented, so are the opportunities.

The big issues are global issues that affect every individual, every locality, and every nation, but issues that can also be affected by action here at home. As Rene Dubos advised us, "Think globally, act locally" (1980, p. 156). The resolution of these issues calls for leaders with broad perspective, with an understanding of the interconnectedness of things, with appreciation of the interdependence of people everywhere, with foresight capability, with a social conscience, and with an independence of thought and action.

Measures of Change

The escalating rate of change in the world today makes the need for such leadership ever more urgent. Consider the following:

When I was in high school, the world's population reached two billion, having taken a century to add the second billion. Now we have added the fifth billion in only 13 years.

The cumulative action of ever more people with ever more wants and ever more tools is having an unprecedented negative impact on the natural resource base, causing the most rapid desertification, deforestation, soil erosion, wetland destruction, groundwater depletion, and species extinction in history (Brown et al. 1986, 1987). We are spending our biological capital most recklessly.

While most people on earth, including us here in this citadel of luxury, are moving toward higher socioeconomic status, more and more children are being born into "absolute poverty," a term coined by Robert S. McNamara, president of the World Bank, to describe "a way of life so degraded by malnutrition, illiteracy, violence, disease, and squalor as to be beneath any reasonable definition of human decency." The World Bank estimated that 780,000,000 people were in this category in 1980 (McNamara 1984).

While our news media report the daily and even hourly rise and fall of the indicators of economic health and entertain us with the rape, murder, terrorist attack, execution, or chemical leak of the day, the most tragic news of all goes unreported. Do you know that 40,000 children died today, 40,000 died yesterday, and 40,000 will die tomorrow (UNICEF 1987, p. 1)? Do you know we fellow human beings have the knowledge and the wherewithal to prevent this? What a subject for investigative reporting -- to ferret out who is responsible for this bungling.

Over and above all this, the nuclear powers continue to squander hundreds of billions of dollars on killing machines that some afternoon or evening could be triggered off by human or mechanical failure, by madness or drunkenness in the chain of command, or by implementation of a first-strike strategy, wiping out much of civilization around the globe, not only in the U.S. and the USSR, but in Asia, Africa, and Latin America as well.

Plants and animals would share a similar fate. Think of this: one species among the millions of species on earth having dealt a crippling blow to life on earth.

Within the lifetime of today's university students, the world will use 80 percent of all the oil the world ever will use, draining the tanks and wells of the source of energy that has powered much of our current way of life (Hubbert 1956; Gever et al. 1986).

And nuclear energy, which 20 years ago was thought to be the answer to our projected huge growth in energy needs, now appears to be on the same track as oil, its production likely to peak in 15 to 20 years and then gradually decline to zero.

The United States, like many other nations, has dumped its wastes into the air, water, and land over many years until today the task of cleanup inherited by the present generation is a Herculean one. The Office of Technology Assessment of the U.S. Congress estimates that it will take 300 billion dollars and 50 years to clean up the hazardous waste dumps in our country, many of which are already leaking poisons into drinking water supplies (Hirschhorn 1985). And the cumulative impact of acid rain and other air pollutants over a number of years kills freshwater fisheries, destroys forests, and corrodes buildings and monuments both here at home and across our borders.

Most of the nations of the world, including the affluent United States, whose debt has passed the two trillion dollar level, are living off borrowed money, mortgaging their children's future and making it more difficult to fund life-protecting projects. The U.S. has moved over the past five years from the world's largest creditor nation to the world's largest debtor nation.

While we talk of peace, wars rage around the world, fueled by armaments given or sold in ever-greater quantities by the big merchants of war: western Europe, the United States, and the Soviet Union. Global militarization squanders resources desperately needed for quality-of-life programs. And the raging wars -- 14 per year on the average since World War II -- slaughter, maim, and destroy property, forests, and crops, adding another huge and unnecessary demand on the world's resources (Myers et al. 1984).

These problems are all interconnected and call for an integrated approach to their solutions. One might conclude it is hopeless and put his head in the sand. But it is not hopeless. We the people of the world can turn this situation around if we work at it, if we demand action by our leaders, if we work together. Each of us can make a difference. And with the right collaborative leadership, together we can reverse the life-threatening trends of today and replace them with life-supporting ones.

Our track record should give us confidence we can do it. Clearly, we have come a long way over the years. I dare say hundreds of millions of us today enjoy a better quality of life than royalty did a few hundred years ago. Life expectancy has more than doubled, with most people on earth now likely to live out three score years and in the process be free of most of the diseases and accompanying suffering that plagued our ancestors. Life expectancy at birth in the developing countries now averages 73 years (Haub and Kent 1987).

Thanks to the Green Revolution and the promise of the Gene Revolution it now appears that the world can produce enough food to feed its current five billion and probably its anticipated 10 billion if the food can be distributed to all the people when they need it (Swaminathan 1986, p. 20). Literacy has skyrocketed, and our ability to store, retrieve, and integrate information has grown to an extent inconceivable a few decades ago, making us much more qualified to define problems and their solutions. Millions annually now take the grand tour not only around Europe but around the globe, and a few have even visited the moon. Most people can, by radio and television, be in contact daily with what is happening around the world, thereby getting to know their world, its problems, and its opportunities.

We now know of successful large-scale efforts around the world to reduce human population growth, to arrest desertification and soil erosion, to replant trees, to reduce pollution and waste, and to manage cropping, grazing, and fishing in sustainable ways. And the largest success story of all is that of China's one billion people in reducing their birth rate close to the replacement level, providing adequate food for all, raising their life expectancy and literacy and lowering their infant mortality rates close to those of the affluent nations while incurring no significant foreign debt and cutting their military budget in half (Brown et al. 1986, pp. 17-21).

Of special note is the accomplishment since World War II of the peoples of the world in building for the first time a large number of governmental and private international organizations such as the United Nations and its affiliated agencies that have clearly advanced the ability of people to learn from each other, to cooperate and help each other, and to resolve conflicts.

Another noteworthy accomplishment is that of the two superpowers in not going to war with each other throughout the 70 years of their coexistence. And finally, we now know how all people and all life are interconnected and interdependent and thus know we are all afloat in the same boat.

So all is not gloom and doom. There are many positive signs to give us hope. But this does not mean that we can afford to be blindly optimistic. The threats to a sustainable, decent quality of life are real indeed and will not go away just because we wish it so. We must work to make it so. None of us knows what the future will be like, but whether we like it or not, each of us will play a role in creating it, for better or worse. Let's consider the big problems, one by one, and what we can do about them.

Poverty, Population, and the Environment

Next to our propensity for killing each other, the worst mark on our record is the huge number of our species still living in poverty. One hundred and fifty years ago the total world population reached one billion. Today we have more than that number living in extreme poverty and half that number under conditions far below what anyone would consider human decency (IUCN 1980). The magnitude of this scar, this failure, is usually hidden by our celebration of our success in providing an ever-higher material standard of living in the developed nations.

Worldwide statistics hardly support the rising-tide theory of economics: that if we facilitate the rise of the more affluent the poor will float up with them. The Population Crisis Committee's human suffering index, based on ten quality-of-life parameters, rates 30 countries with 519 million people as experiencing extreme human suffering and 44 additional countries with 2.85 billion people experiencing high levels of human suffering (Camp and Speidel 1987).

The time is long past due for a more direct and more adequate assault on poverty. The poor must and can do most of the job themselves, but they can benefit markedly from help and less negative interference from the more affluent.

Ample food production worldwide is not enough if the food does not get to the people when they need it. Today there are more than 300 million tons of grain reserves around the world and hundreds of millions of hungry people (Swaminathan 1986, p. 20). For each country to learn how to produce and store its own food and for nations to make food available to the poor who cannot afford to buy it should be priority goals.

The smaller the population growth of a country, the less the difficulty of providing for the needs of the people. There is an almost perfect correlation (a Pearson coefficient of 0.83) between the human suffering index in a nation and its rate of population growth (Camp and Speidel 1987). More poor people must be given the knowledge and wherewithal to limit their family size, that is, to be able to exercise the same choice as the more affluent already do. Like the affluent, they also need assurance their children will live. Toward that end, the program led by UNICEF, the United Nations Children's Fund, to vaccinate all children of the world by 1995 against the childhood diseases that kill and incapacitate millions annually needs our strong support.

The poor in subsistence economies, scrounging for a living, are, through overcropping, overgrazing, and overcutting of trees, devastating the resources upon which their livelihood depends, causing desertification, deforestation, soil erosion, and reduced water supply.

A larger impact on the world's natural resource base and much of it in poor countries comes from the escalating demand of the affluent nations, a good share of it caused by waste and inefficient use of resources. One U.S. citizen, for example, exerts 50 times the demand on the world's natural resources as does an Indian or a Chinese (IUCN 1980).

To see that the overall annual demand for resources does not take more from the earth's natural systems than these systems can replenish annually is the prime challenge to providing a sustainable and decent quality of life for future generations.

A measure of the magnitude of the job to be done is the projection that, even with optimistic success in family planning, the world's population will double to 10 billion before it stabilizes. And nearly all this growth will be in poor countries (Haub and Kent 1987).

Poverty both causes and results from ecological decline. Population growth both causes and results from poverty. Ecological decline is exacerbated by population growth, poverty, and wasteful and inefficient use of resources. They all must be considered together. Everything is interconnected.

To deal with these problems we need to replicate on a large scale the many successful projects that have already been demonstrated around the world, such as planning families, planting trees, terracing croplands, selecting optimum crops, and limiting livestock to the grazing capacity of the land. We also need to launch a markedly expanded effort to reduce waste and inefficiency. The opportunities to do so are large. This is especially true in the industrialized nations and in the development and use of energy.

International banking institutions such as the World Bank need to stop funding projects that are ecologically destructive, such as their disgraceful cattle-raising project in Botswana (Turner Broadcasting Co. 1985).

To fund constructive activities we need to tap half of the trillion dollars now budgeted annually for the world's armed forces, which today constitute a super threat to the world's security. Remember, China and Argentina have already cut their military budgets in half. Japan spends less than one percent of its gross national product on the military, and Costa Rica does not spend anything on this activity. In so doing we could put some of the one-half million scientists now working on creating better killing machines (Brown et al. 1986, p. 199) to work to improve human health, raise food where it is needed, develop better contraceptives, control pollution, and develop new energy technologies.

Of the factors contributing to poverty I believe excessive population growth in the developing countries is the most serious. All the developed nations have lowered their birth rates close to or below the replacement level (2.1 children per woman). Hundreds of millions of parents in those affluent countries, striving to build a good quality of life for themselves and their children, have, on the average, voluntarily opted for the two-child family. Now hundreds of millions of poor parents in developing countries, having been provided the knowledge and wherewithal to limit their family size, are also doing so (Haub and Kent 1987). The challenge is to provide the same opportunity for the hundreds of millions of others still experiencing high fertility.

The United States has been the world leader in furthering family planning under both Democrat and Republican presidents. Now President Reagan, through administrative action, has made us the world spoiler. He has cut off U.S. funding to the two largest and most effective international family planning groups -- the United Nations Fund for Population Activities (UNFPA) and the International Planned Parenthood Federation (IPPF). And now he has announced his plan to withhold funds from U.S. domestic clinics if they do not conform to his personal ideological commitment on the abortion issue. He does this in support of the antiabortion minority groups in the United States.

Neither UNFPA nor IPPF has used any U.S. funds for abortion-related services, in conformity with a 10-year-old U.S. law against such use. By withholding the funds, President Reagan has prevented millions of poor women from avoiding unwanted pregnancies and, in so doing, contributed to hundreds of thousands of abortions and the birth into absolute poverty of large numbers of children who will suffer and die from hunger and neglect. What a crime against humanity! What a shame that so few American leaders speak out on this presidential disservice! My choice here is to lobby the Congress to reverse the president's policy. The best way to prevent abortions is to prevent unwanted pregnancies, and the best way for us to help stabilize the world population is to expand our funding of family planning worldwide.

The Nuclear Threat

Now let us focus on the biggest threat of all to life and to achieving a decent and sustainable quality of life in the 21st century -- nuclear war. I do not have time to discuss this issue in any depth, but let me make a few suggestions.

First, I believe it is extremely important that much more be done to educate people everywhere, including our leaders, on the biological consequences of nuclear war, a cost to humanity far beyond any conceivable benefit that might accrue from such war. As Professor John Kenneth Galbraith has written about the results of a nuclear exchange between the superpowers, "No one, not even the most talented ideologue, will be able to tell the ashes of capitalism from the ashes of socialism."

The consequences of a U.S. and USSR nuclear exchange would include not only the billion people estimated by the World Health Organization that would be immediately evaporated, blasted, or irradiated to death but also a larger number dying from nuclear famine caused by an average 22- to 30-degree Fahrenheit drop in temperature, devastating agriculture. The temperature drop would result from dense clouds of smoke lofted into the atmosphere from fires generated by the bombs. This new scientific analysis, first reported in 1982 and subsequently confirmed by many investigators around the globe, had been missed by scientists and military planners for 37 years (Harwell and Hutchinson 1985; Scientific Committee on Protection of the Environment 1987). Calculations indicate that noncombatant India, for example, would lose more people from famine than the U.S. and USSR would together lose from the immediate impacts of a nuclear exchange.

If the people of the world really understand the consequences of nuclear war, then the presence of the nuclear bomb may well provide the means of avoiding armed conflict of any kind between nuclear powers, assuming that no madman or fanatic gains leadership of such a nation. It is hard to believe that a nuclear power in the process of losing a war involving only nonnuclear weapons, would, in the hatred, fear, and confusion of the battle, refrain from using its most potent weapons -- its nuclear weapons. And it is easy to conclude that an agreement to get rid of all nuclear weapons would be the most dangerous of all, for any advanced nation in a nuclear-free world could in a few weeks produce such weapons and then hold the world hostage.

This reasoning leads to the conclusion that nuclear powers must, in order to insure their survival, avoid armed conflict of any kind with another nuclear power. This in turn calls for thorough education of the people of the nuclear powers by their leaders, educators, and journalists about the consequences of nuclear war, both immediate and long-term. And it calls for each nuclear power to maintain a small number of accurate nuclear weapons, say five percent of what the U.S. now has, to control scrupulously their potential use, and to prevent launching by mishap or malfunction.

To hold out to the people the possibility that the world might get rid of all its nuclear weapons, or that man could design a magical net that would safely intercept all offensive nuclear weapons no matter now inventive their creators might become, or that nuclear powers might settle their differences through conflict using only conventional armaments, is wrong. Those are three cruel hoaxes. They distract people from what is ultimately the only solution, that is, to learn to get along without going to war.

You and I need to contribute to this cause. We need to select carefully and then influence our leaders. We can also be citizen diplomats, arranging joint enterprises and studies with potential enemies. We can begin to look at our former enemies as fellow survivors.

Technology and Environmental Sustainability

Now let us look at another area that requires our attention if we are to provide for a sustainable and decent global balance in the 21st century. We must give much more attention routinely to the longer-range impact of our decisions. For example, society needs more of a say in the type of technology that is used to satisfy its needs. My experience in industry in developing and launching new technologies and as director of the Office of Technology Assessment of the U.S. Congress persuaded me of this.

Technology has important impacts over the short term and long term, locally and globally, on social, environmental, economic, and political factors. Thus, in making choices toward a sustainable society that provides livelihood security for all, we cannot leave the choice of technology strictly to consideration of the financial return to be gained by those who invest in it.

Unfortunately, such a view gets one embroiled in ideological battles over how the means of production should be controlled. The environmental movement has demonstrated the need for governmental regulation of technology to control pollution. The marketplace will not do so. Nor will the market properly represent the interests of future generations or of people who have no wherewithal to participate in market decisions.

The current major problem resulting from the dumping, over decades, of hazardous wastes in landfills, deep wells, and streams stems from short-term market-oriented decisionmaking. Now society, with growing concerns about the impacts of hazardous wastes on health, is picking up the multibillion dollar tab to clean up the inherited mess. With a little foresight, communities could have avoided this cumulative assault on their environment. Through governmental regulations and enforcement, society is now leading industry to stop the waste at its source by developing technologies that do not produce as much hazardous waste or that recycle or recover valuable components from the previously categorized "waste stream." And in many cases the new technologies or new processes prove to be quite profitable (Leung and Klein 1975).

Another example of industry and government getting society in deep trouble because of lack of foresight is the decision to rush ahead with nuclear energy. Near-term market consideration led to the conclusion that nuclear energy would be "too cheap to meter." The promoters of nuclear energy ignored the huge government subsidies provided through the companion state-run nuclear weapons industry and failed to face up to long-term safety, waste-disposal, and plant-decommissioning problems and to the creation of large, uninhabitable areas such as those caused by the Soviet Chernobyl disaster. As a result, the U.S., which led in the development of the nuclear energy industry, is now leading in its demise. Here is how one of the world's leading business magazines, *Forbes*, described the situation in 1985: "The failure of the United States nuclear power program ranks as the largest managerial disaster in business history, a disaster on a monumental scale" (Cook 1985, front cover).

We in the U.S. and other western nations are proud of our free-enterprise, market-oriented economies and rightly so. The record clearly shows how the countless market decisions of hundreds of millions of us day after day functioning as Adam Smith's "invisible hand" have steered a course to the great benefit of most of us. But the record also shows that such a system can be corrupted by the decisions of a powerful few acting in their own self interest and/or in ignorance or denial of the long-term or global consequences of their decisions. In light of today's understanding, Adam Smith would probably have called this force the "invisible foot." It will kick us in the future if we ignore the long-term and global consequences of our present actions.

The impact of the invisible foot is well exemplified by the nuclear energy and hazardous waste disasters I have discussed. Other examples are the long-term impact of dumping pollutants into the air on human health, forests, lakes, and buildings; the cumulative impact of excessive tree cutting, excessive wetland filling, overgrazing, cropping, and overfishing in reducing nature's capacity to replenish these resources; and the impact of cigarette smoking in causing lung cancer 20 to 30 years in the future.

Certainly the biggest invisible foot we have created in our rush to satisfy a need of the moment is the threat of nuclear war, as I discussed earlier. In our desire to protect our way of life from an immediate enemy, real or perceived, our U.S. central government has planned and built a nuclear arsenal that now is the real enemy, the greatest threat of all to that which we have sought to protect. The Soviets, French, British, and Chinese have done the same and put themselves in the same predicament. Maybe now that we all have this common enemy we can work together peacefully to tame it.

Opting for Sustainability

If we are to provide for a sustainable global society, for global balances in the 21st century that will insure successive generations a decent quality of life, we need to stop creating invisible feet in the present. What can we do to avoid this problem? Here are several suggestions.

First, our educational institutions should produce professional generalists through rigorous undergraduate and graduate training to think comprehensively, globally, and long-term; to understand the interconnectedness and interpendence of all life and its dependence upon the air, water, soil, and sun; to be able to integrate the technical, economic, social, environmental, and political variables involved; and to assess quantitatively and qualitatively the long-term impacts and feedbacks of one's decision. This is the training required for the most important jobs in our society. Yet no institution provides it.

Universities, especially graduate schools, are bogged down in the specificity of their disciplines. Here is how University of Wisconsin professor Aldo Leopold, put it: "All the sciences and arts are taught as though they were separate. They are separate only in the classroom. Step out on the campus and they are immediately fused" (Leopold 1942, pp. 486-87).

I do not mean to belittle specialized training. I spent four years here at Madison getting my Ph.D. working long hours seven days a week on my dissertation topic, "Inhibition of the Air Oxidation of Vitamin C." Digging deeply and narrowly is important and has served us well in pushing back the frontier of knowledge. But it is not very useful for training the key decisionmakers in our society or in preparing us to be effective world citizens.

Probably the most significant scientific discovery of the past century and to which Aldo Leopold contributed was the understanding of the global interconnectedness and interdependence of all life and of the global and long-term impacts and feedbacks of individual actions. It calls for that new type of training I have mentioned -- a new discipline -- that cuts broadly across the other disciplines and can function effectively at the interfaces between disciplines, integrating their fields of knowledge. In my view the time will come when such training will rank among the highest universities provide, and the leadership positions in society will be dominated by professional generalists with Ph.D.'s in integrated studies.

My second suggestion for avoiding the invisible foot is that our society in and out of government establish institutions that will provide decisionmakers and the general public with some foresight capability. Nowhere in our government today do we have such facility. We are flying blindly into the future.

Technology assessment and the the environmental impact statement are two good developments instituted by our government, but they provide only a small part of what is needed. Legislation has been introduced in Congress to establish new institutions to provide more foresight capability -- to analyze trends and interactions, to define problems and opportunities, and to present various choices for action (Senate Bill 1171, 1987). However, it has little current support in Congress, where the paranoia about governmental planning sets us up for future catastrophes.

My third suggestion is that we recognize that a market-oriented economy and government planning and controls are complementary. Neither can do the job alone. When analysis shows that the forces of the marketplace will work, that is the way to go. For example, heavy government subsidies for nuclear energy and fossil fuels should be removed so that the market can establish how effectively more efficient use of energy and renewable sources of energy can compete. On the other hand, when analysis shows the market will not work, as in the protection of the mental health of children by removing lead from gasoline, then government regulation

should be used. After such regulation was imposed in the U.S., the lead emitted into the environment decreased by 86 percent, and a major reduction in the amount in the blood of children followed.

When world citizens are both free to vote with their money in an unsubsidized marketplace and free to vote for their governmental leaders in an unfettered polling place, then the foundation is laid for making the optimum choices between the market approach and the regulatory approach.

It is encouraging that many countries are moving from excessive or total reliance on government controls to greater use of market mechanisms, with very promising results. China, Hungary, and Zimbabwe are good examples. And recently even the Soviet Union has started to move in this direction.

The continuing conflict between environmentalists and the right wing in our country stems from the antienvironmentalists setting up a straw man and then tearing him down. They call environmentalists "doomsayers" with an "unjustified crisis viewpoint" and point to environmental cleanup successes of the past as proof that society left alone by government will also correct the current problems. They ignore the fact that those successes stemmed from citizen pressure and government action. As for environmentalists, they are proud of their role in past successes and are diligently applying the lessons they have learned to the threatening trends of today to prevent doomsdays. The right-wingers promote a muddle-through approach, whereas environmentalists promote an activist, solution-oriented approach. Both groups think the problems can be resolved, and both express hope that they will be.

So why all the fuss? Here's why. The right wing's all-out opposition to governmental controls makes them see environmentalists as socialists. A September 1985 paper prepared by the American Enterprise Institute calling for the establishment of a Center for Population, Environment, and Development Studies clearly defines their hang-up. It states that environmentalism leads to drastic solutions "often involving massive applications of centralized power, to the detriment of private choice," which "breeds planning, controls and bigger government" (Wattenberg et al. 1985).

Today 80 to 90 percent of U.S. voters are in favor of more government action to clean up the environment even if it costs them more money (Louis Harris and Associates 1985, 1986). They know that market forces were at work over the decades when their environment was being progressively and seriously degraded. I believe they share the view I expressed earlier: Rely on market forces when they work, government intervention when they do not.

Toward a Sustainable Planet Earth

Let me conclude my remarks this way.

The basic knowledge of what needs to be done to provide for desirable global balances in the 21st century, as I have tried to show, is already with us. What is missing is the will -- the will of millions of us, but especially of our leaders -- to face up to the threatening trends of today and change them.

We especially need decisionmakers with a holistic perspective -- a comprehensive, global, long-term perspective -- and the ability to integrate the many interdependent forces at work around the world and analyze their prospective cumulative impact before making choices for action.

And you and I need to stand up and be counted. It is not enough to be an expert in a discipline -- to be an author of a research paper -- to have the answers to a critical problem. One must put such competence to work -- come out of one's research lab or office to participate in the real world -- to be an effective world citizen. The world can't afford its talented people camping out in the comfort of a narrow pasture.

As Goethe wrote:

Whatever you can do, or dream you can, do it.
Boldness has genius, power and magic in it.

Our hope for the future for a sustainable, decent quality of life for future generations globally is enhanced, as I mentioned earlier, by the greatest scientific discovery of the past century, the discovery that all life is interconnected and interdependent.

Humanity will thrive as the Earth thrives, but the Earth's health is dependent upon how humanity treats her. Each of us can make a difference, for the worse or for the better. We can remain part of the problem or become part of the solution. By choosing the latter we can gain a good measure of self-fulfillment.

Toward this end, I wrote in 1973 a Declaration of Interdependence (Peterson 1973). In closing, let me share it with you.

We the people of planet Earth
With respect for the dignity of each human life,
With concern for future generations,
With growing appreciation of our relationship to our environment,
With recognition of limits to our resources,
And with need for adequate food, air, water, shelter,
health protection, justice and self-fulfillment,
Hereby declare our interdependence;
And resolve to work together in peace
And in harmony with our environment,
To enhance the quality of all life everywhere.

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